HUMAN REPRODUCTION

***

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Reproduction in Human

Gametogenesis

↓

Insemination

↓

Syngamy (Fertilization)

↓

Development of Embryo (Blastocyst stage)

↓

Implantation (=Nidation) of embryo to uterine wall

↓

Gestation Period (280 days/40 week)

↓

Parturition (Child delivery)

↓

Lactation

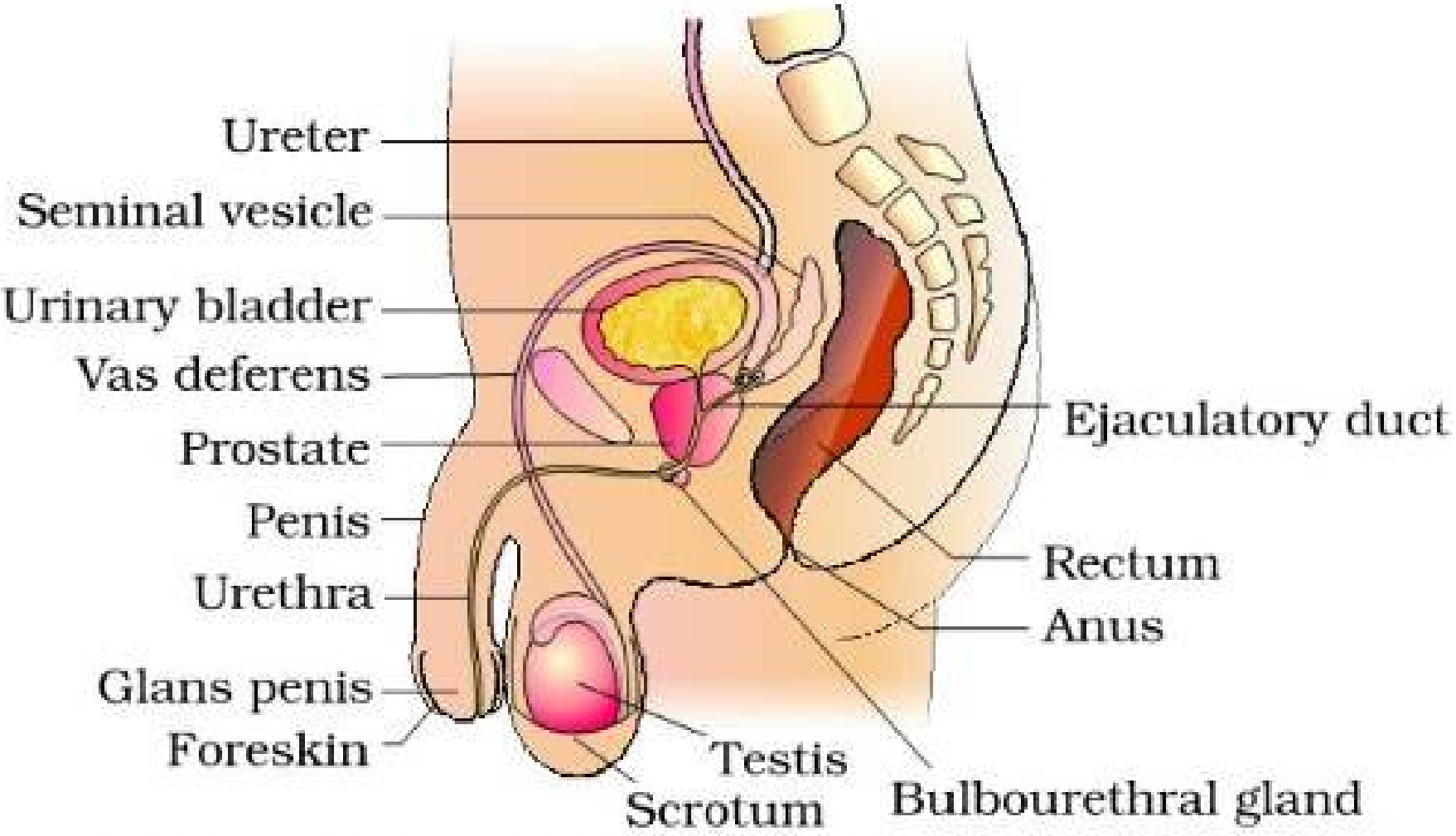


Figure 3.1(a) Diagrammatic sectional view of male pelvis showing reproductive system

Male Reproduction System

Primary Sex Organ

– Testes
* 4-5cm long
* 2-3 cm wide
* 1 pair in Scrotum (Pouch)
* Outside abdominal cavity
* 2-2.5°C lower than body temp.
* Oval shape
* Covered by Mesorchium
* Spermatid Cord
* Gubernaculum
* Dartos & Cremaster muscles
* T. Albuginea
* Testicular Lobules (250 in each)

Accessory Ducts

1) Rete testis (network)
   – all seminiferous tubules opens into it
2) Vasa efferentia
   – 12-15, takes sperm out from testis (Leaves testis)
   – Opens into epididymis
3) Epididymis
   – highly coiled tube
   – on post. surface of testis
   – Ciliated epith. (Stereo-cilia)
   – 3 parts (cuput/Corpus/Cauda)
   – Temporary storage & maturation of sperms
   – Lead to vasa deferens
4) Vasa deferens
   – extension of Cauda epididymis
5) Ejaculatory Duct
6) Urethra

External Genitalia

– Scrotum
– Penis

Accessory Reproductive Glands

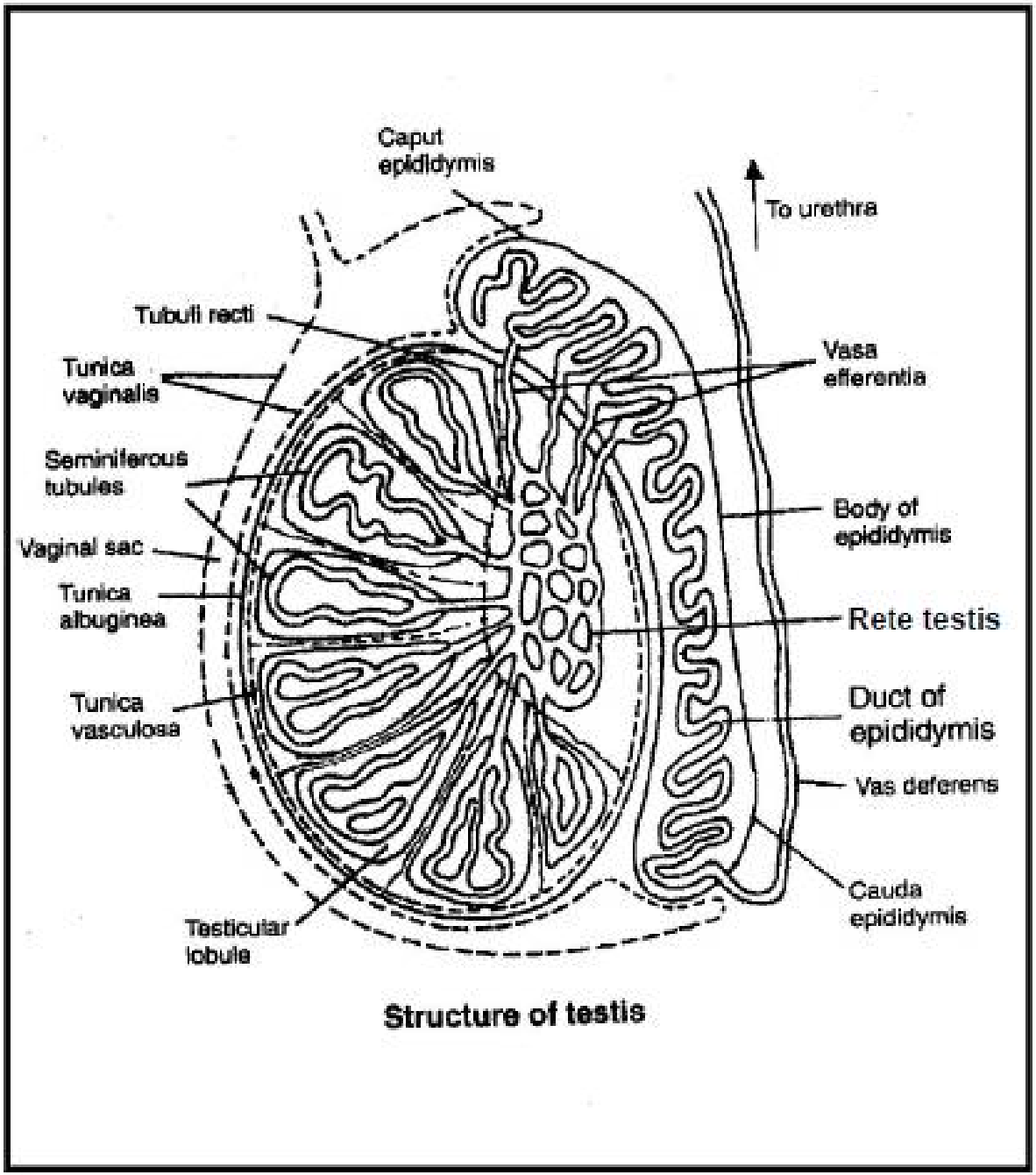
– Seminal vesicle
– Prostate
– Cowpers/ Bulbourethral

Male reproductive system:

- Testis- formed inside abdominal cavity and descend into scrotum during seventh month of pregnancy
  - ✓ Left testis- lower
  - ✓ Intra-abdominal testis – Elephants, whale, dolphin, oviparous mammals

Functions:

1. Sperm formation
2. Androgen formation
   a) helps in spermatogenesis
   b) helps in sperm maturation in epididymis
   c) male secondary sex organ development and maturation
   d) male secondary sex characters development and maturation
   e) responsible for libido (sex desire)
   f) descend of testis



Structure of testis

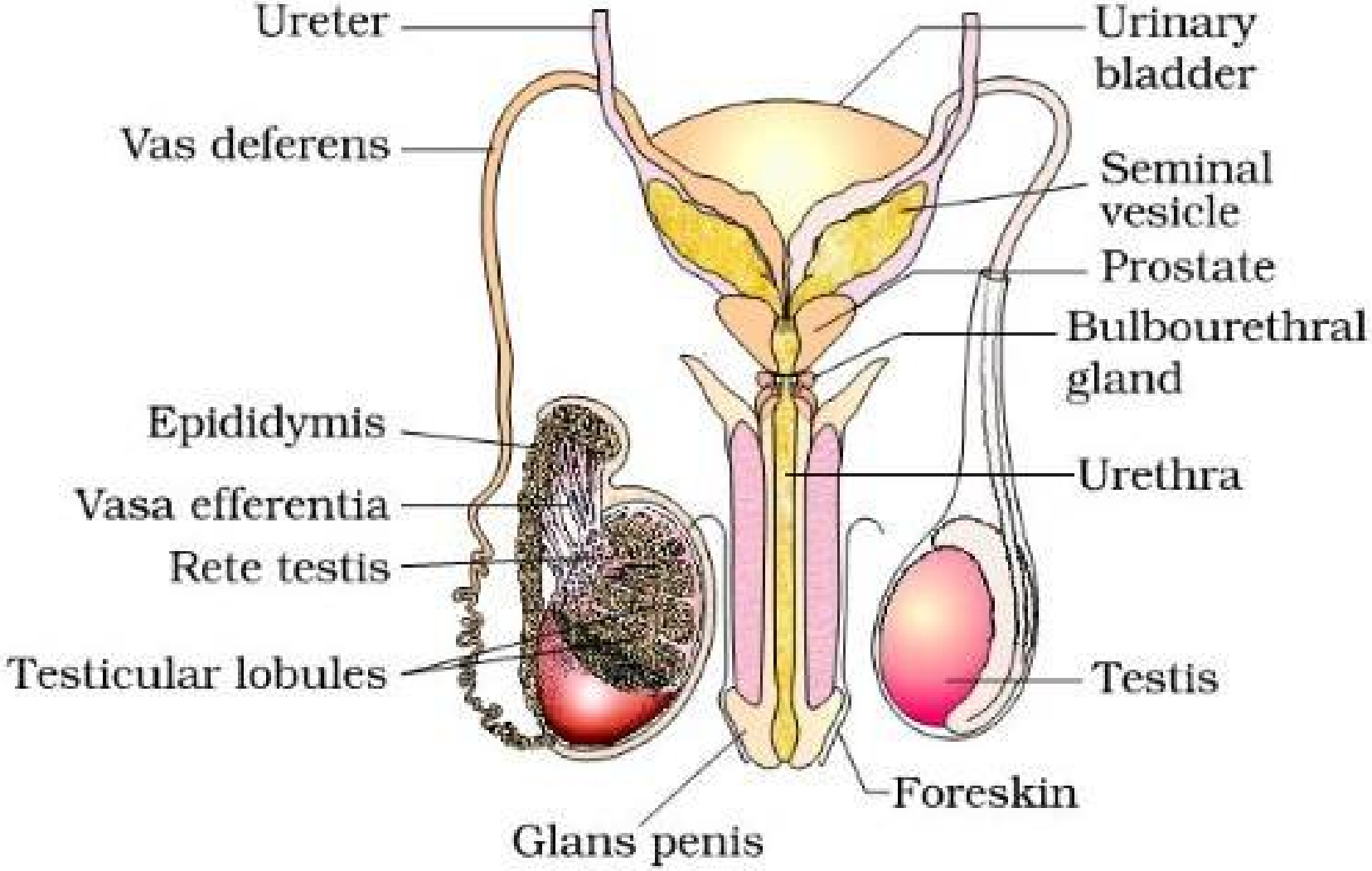


Figure 3.1(b) Diagrammatic view of male reproductive system (part of testis is open to show inner details)

- ✓ Structural and functional unit of testis – seminiferous tubules
- ✓ cryptorchidism
- ✓ monorchidism- e.g. ascaris
- ✓ Vasa deferens ascends to abdomen (through spermatic cord), loops over urinary bladder, receives a duct from seminal vesicle and opens into urethra as ejaculatory duct
- ✓ Pseudostratified stereo-ciliated epithelium
- ✓ Ejaculatory duct – enters into urethra, after passing through prostate gland, extends through penis to its external opening called urethral meatus

- **Seminal vesicle secretions –**
  - ✓ Alkaline (pH 7.2-7.8)
  - ✓ 60-70% of semen
  - ✓ Fructose (sperm nutrient, forensic test for rape)
  - ✓ Prostaglandins – induce contraction in female reproductive tract
  - ✓ Fibrinogen, clots semen

- **Prostate gland secretion -**
  - ✓ Alkaline
  - ✓ 25-30% of semen
  - ✓ Calcium and phosphate ions etc

- **Cowper's/ bulbo-urethral gland secretions-**
  - ✓ Transparent, alkaline, lubrication of penis and neutralise acidity of urethra and vagina (pre-ejaculatory fluid)
- **Penis- copulatory, external genitilia**
  - ✓ Glans penis – enlarged end, covered by foreskin
  - ✓ Tyson glands – on prepuce ,secretes smegma (lubricates glans penis)
  - ✓ Corpora cavernosa – 2 dorsolateral
  - ✓ Corpus spongiosum – single ventral
  - ✓ Erection of penis – facilitates insemination (parasympathetic ANS)
  - ✓ Ejaculation – forceful release of semen (sympathetic)

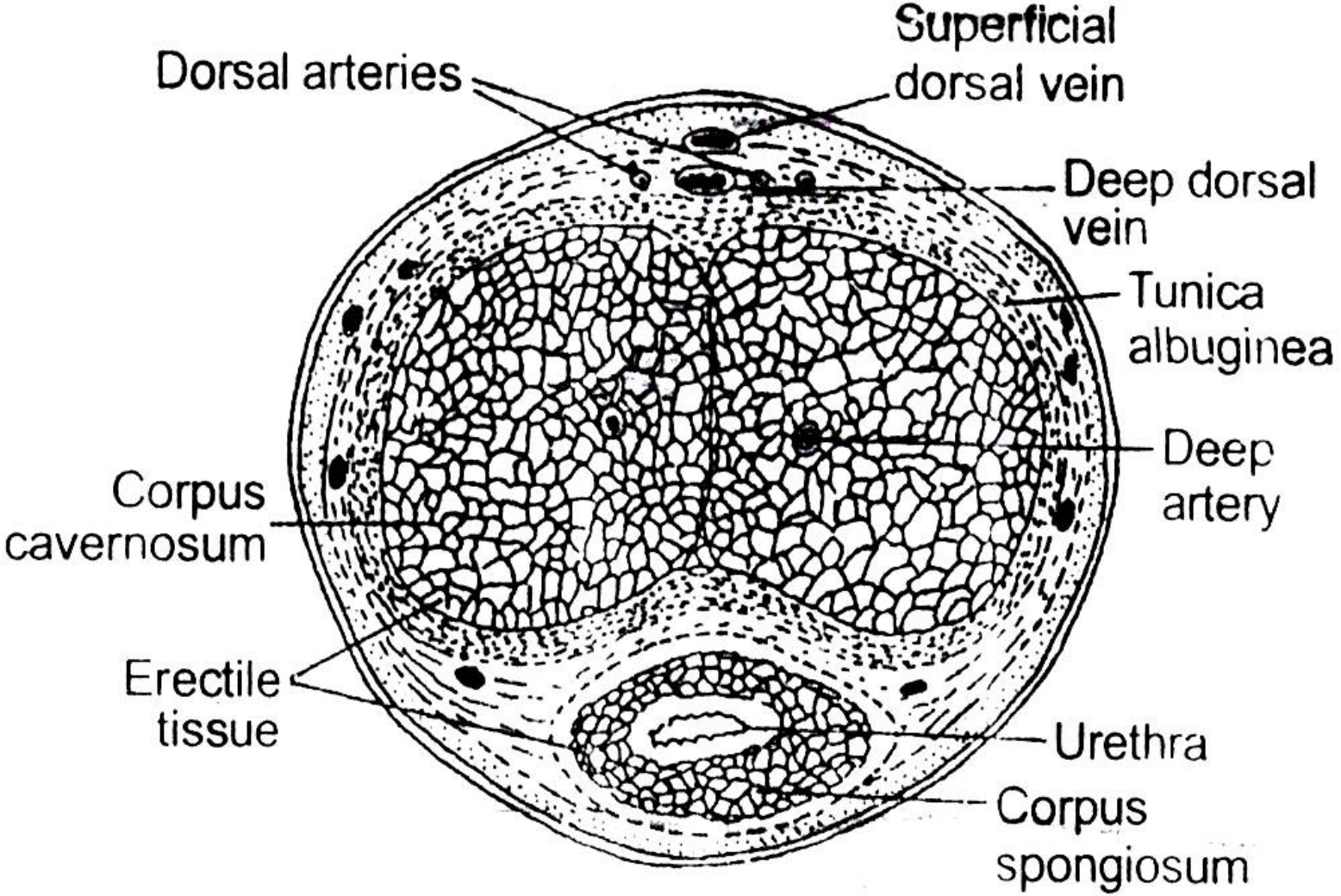
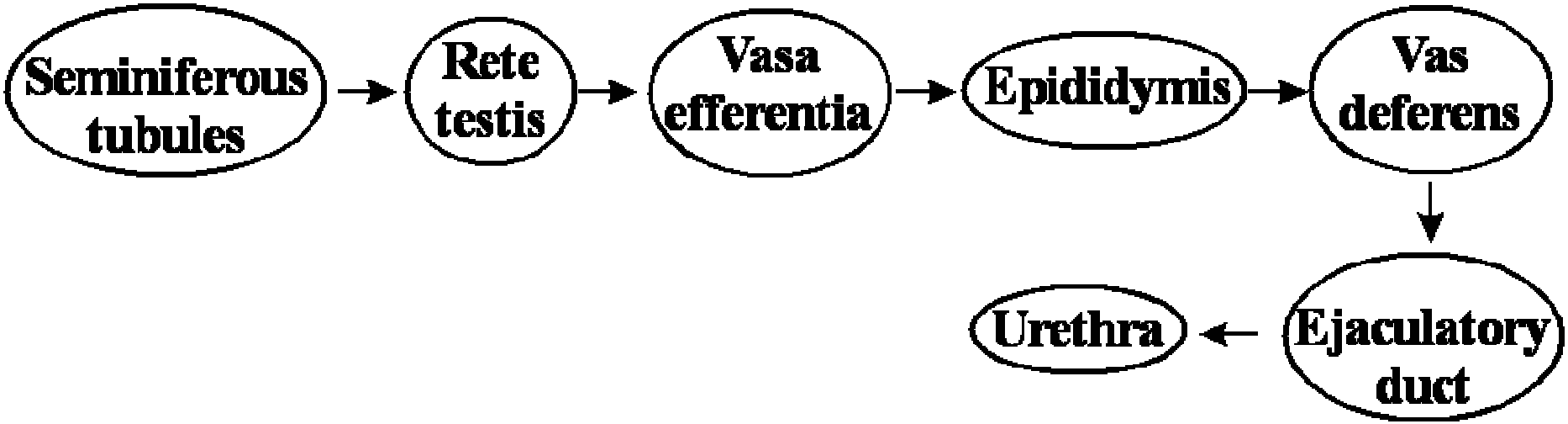


Fig. : T.S. of Penis

Path of Sperm through the Male Body



- **Semen – white, alkaline (7.2-7.4), viscous**
  - ✓ Quantity – 2-3 ml /intercourse
  - ✓ 1 ml semen- 100 million sperms
  - ✓ 1 ejaculate: 200-300 million sperms
  - ✓ Normal semen – 60% motile and 40% normal morphology
- **Seminiferous tubule –**
  - ✓ Male germ cells – simple cuboidal
  - ✓ Sertoli cells – nourishing to sperms
- Leydig/interstitial cells - in between s.tubules, produce Androgens , stimulated by LH/ICSH (ant.pituitory)

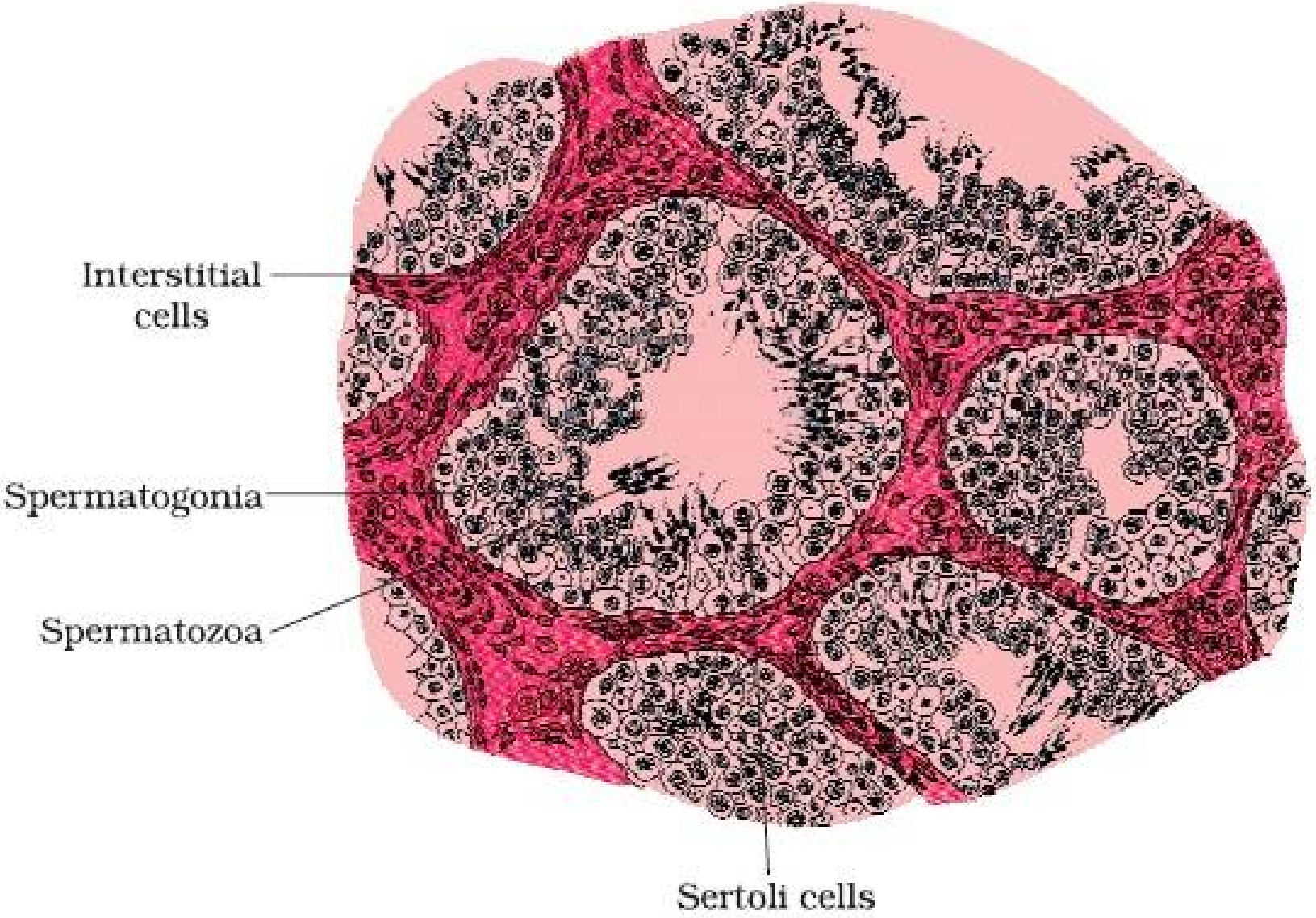


Figure 3.2 Diagrammatic sectional view of seminiferous tubule

- Functions of sertoli cells/sustentacular /nurse cells – columnar

1. Nourish sperms
2. Act as barrier to protect sperms (sertoli cells barrier)
3. Phagocytise dead and abnormal sperms
4. Produce aromatase enzyme -converts testosterone into estradiol (essential for sperm sustenance)
5. Produce three hormones (AIM) -
   A) Andogen binding protein- concentrate testosterone
   B) Inhibin- suppress FSH
   C) Mullerian inhibitory hormone

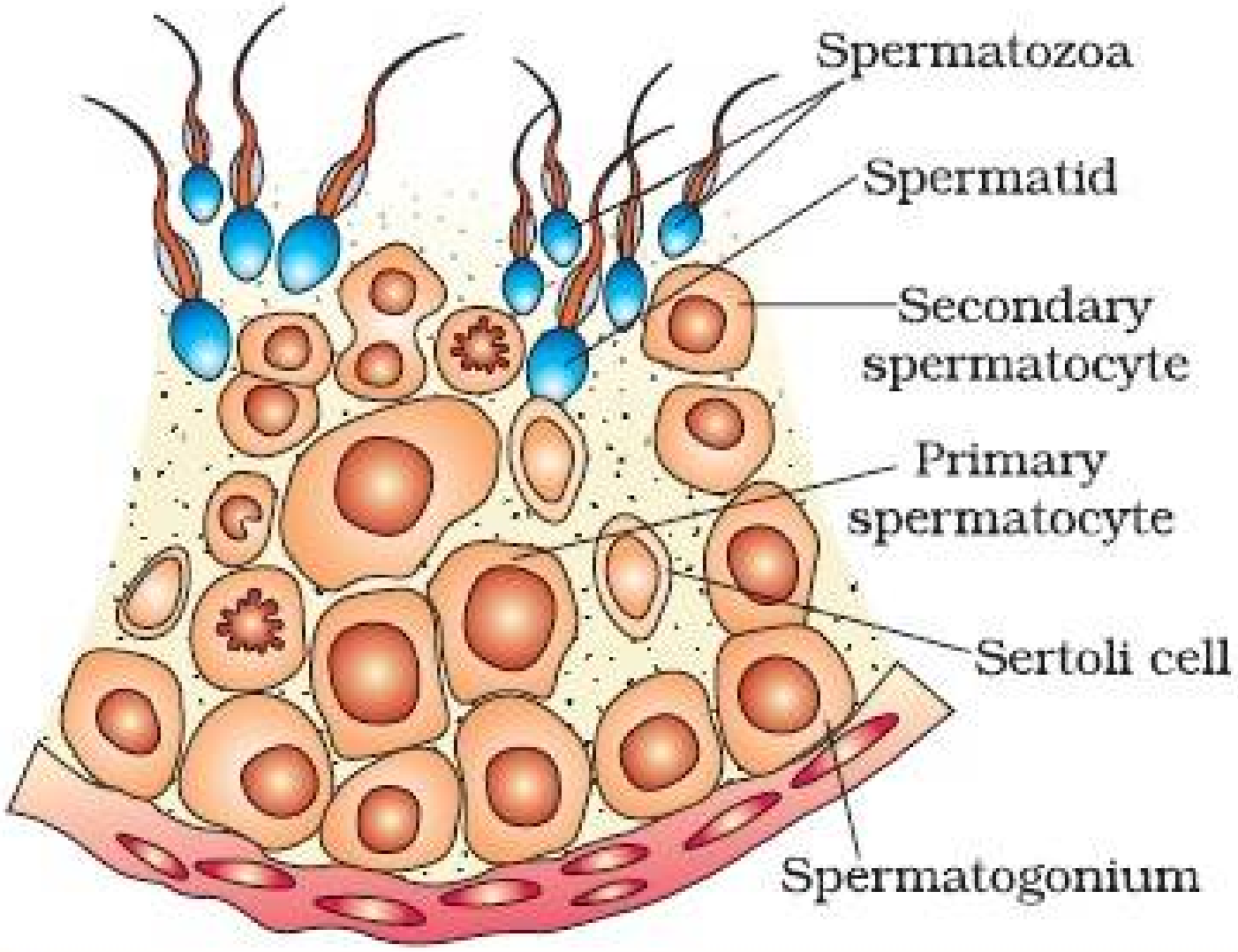
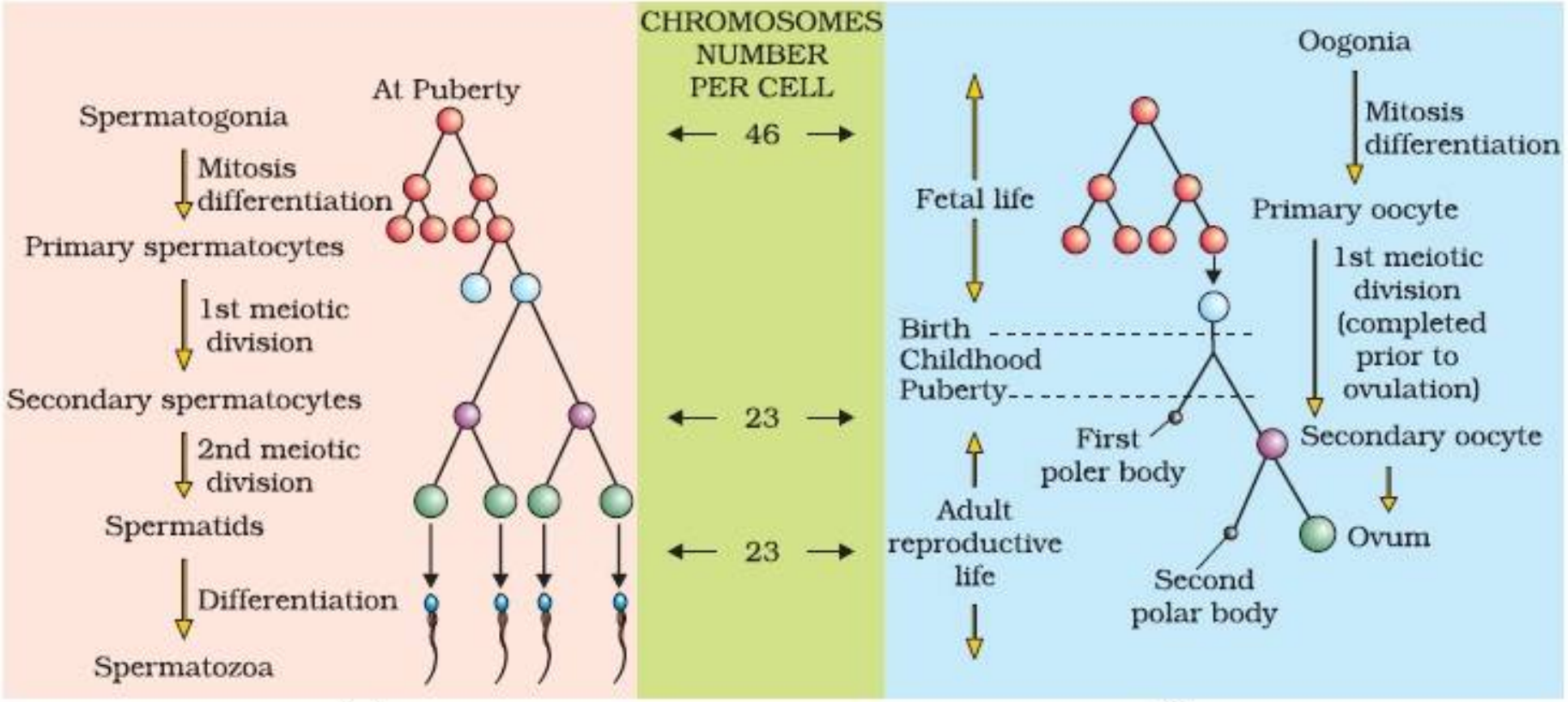
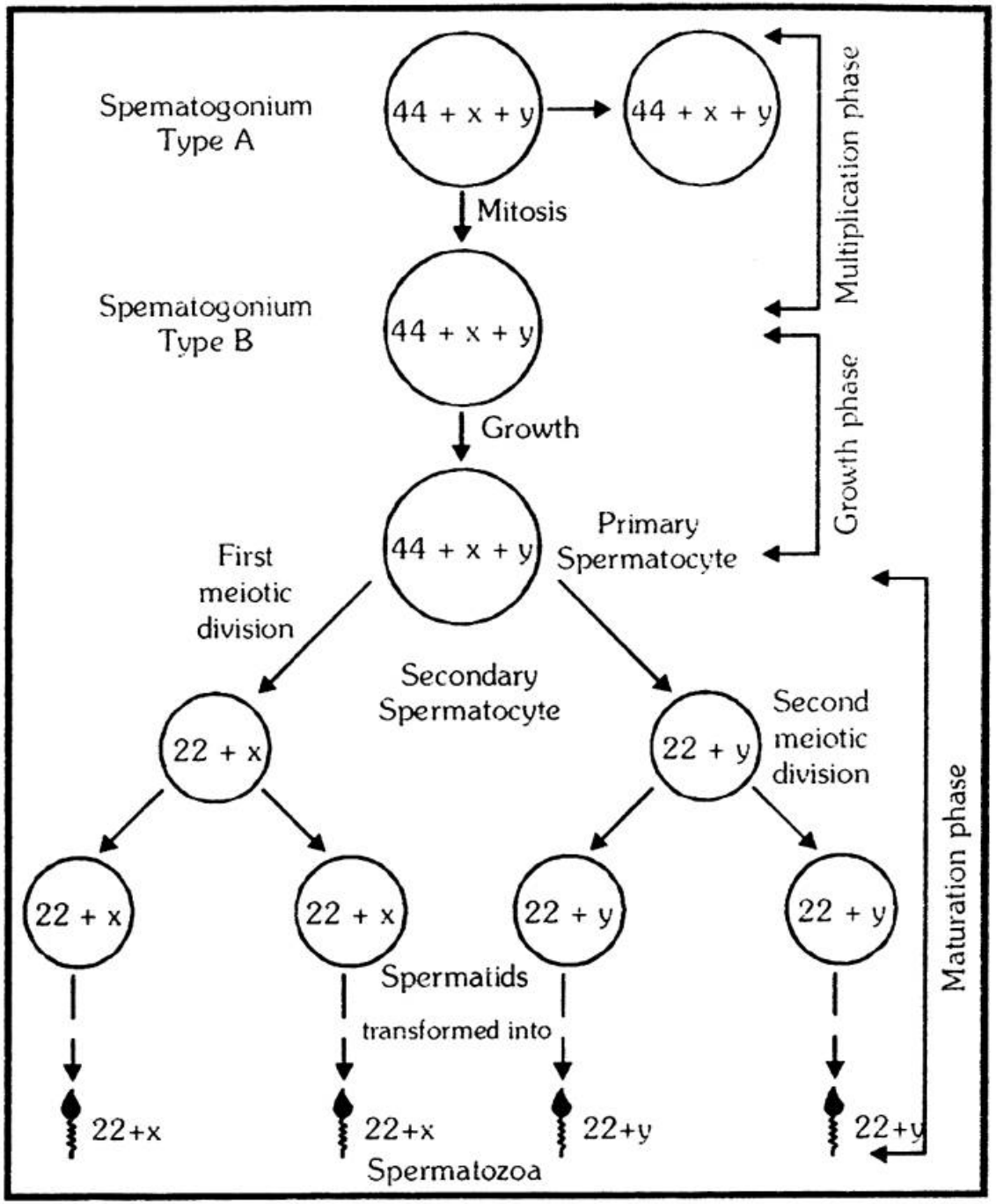


Figure 3.5 Diagrammatic sectional view of a seminiferous tubule (enlarged)

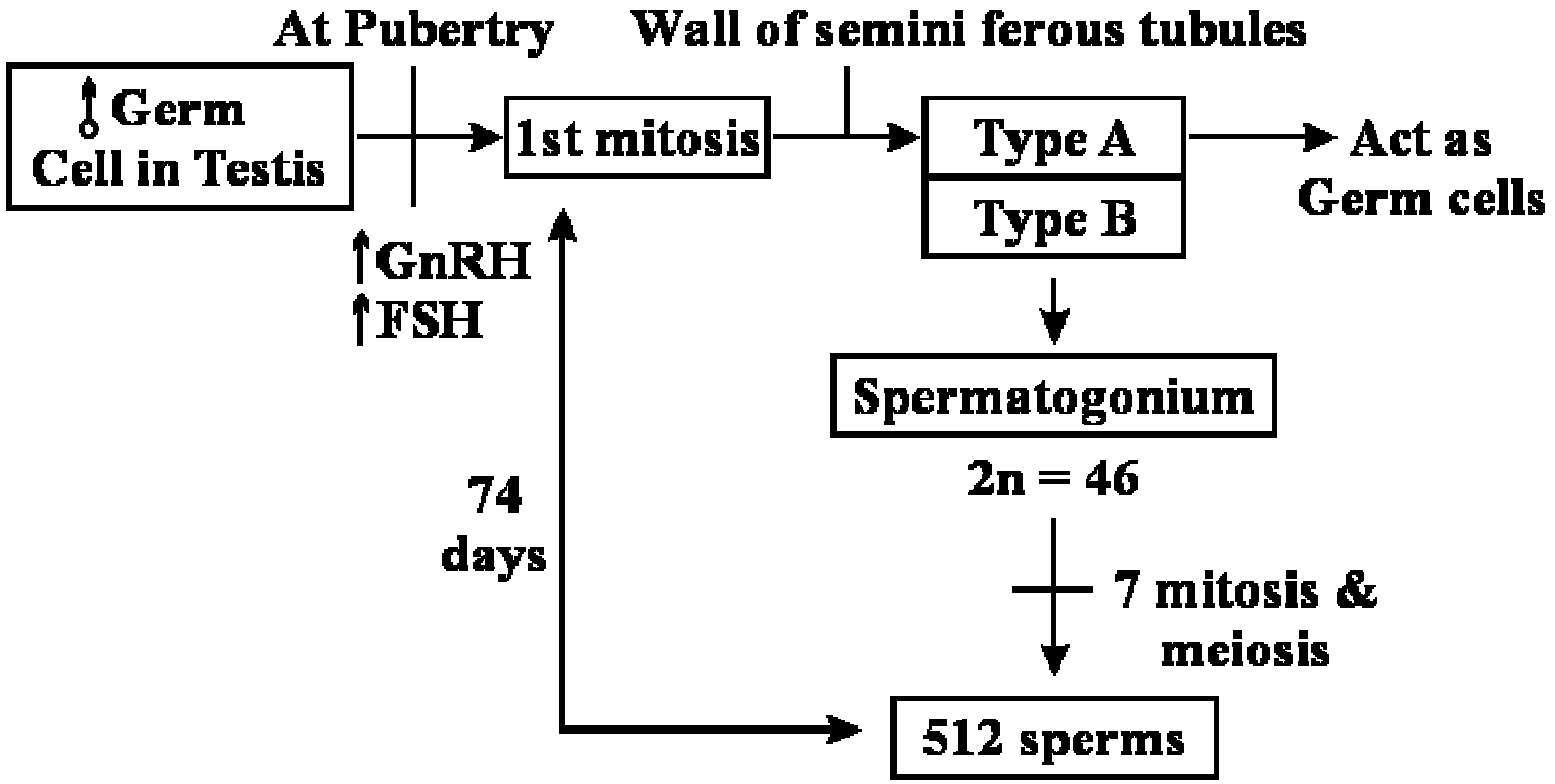

At Puberty
Spermatogonia
Mitosis differentiation
Primary spermatocytes
1st meiotic division
Secondary spermatocytes
2nd meiotic division
Spermatids
Differentiation
Spermatozoa
CHROMOSOMES NUMBER PER CELL
46
23
23
Oogonia
Mitosis differentiation
Fetal life
Primary oocyte
1st meiotic division (completed prior to ovulation)
Birth
Childhood
Puberty
First poler body
Secondary oocyte
Adult reproductive life
Ovum
Second polar body

(a) (b)

- **Spermatogenesis –**
  - ✓ Inside seminiferous tubules
  - ✓ Starts at puberty – effect of GnRH and FSH
  - ✓ Three stages –
    1. Multiplication phase- (mitosis) - spermatogonia produced (2n)
    2. Growth phase – primary spermatocyte (2n) formed
    3. Maturation- meiosis- spermatid (n) formed
  - ✓ Followed by spermiogenesis/ spermateleosis - transformation of spermatid into sperms
  - ✓ Spermiation
  - ✓ One primary spermatocyte – four sperms

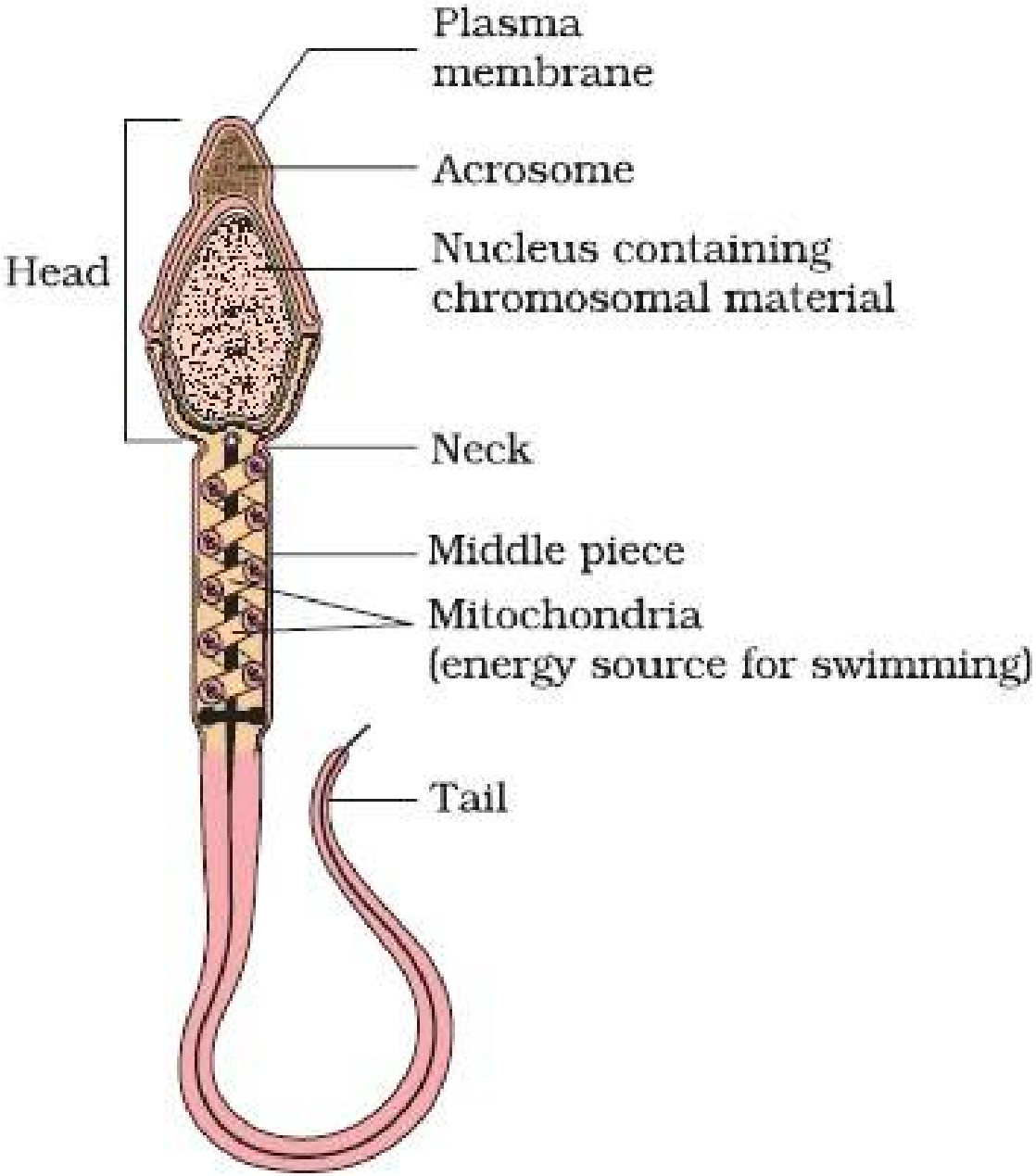

Spematogonium
Type A
44 + x + y
44 + x + y
Multiplication phase
Mitosis
Spematogonium
Type B
44 + x + y
Growth phase
Growth
44 + x + y
Primary
Spermatocyte
First
meiotic
division
Secondary
Spermatocyte
22 + x
22 + y
Second
meiotic
division
22 + x
22 + x
22 + y
22 + y
Spermatids
transformed into
Maturation phase
22+x
22+x
22+y
22+y
Spermatozoa

Spermatogenesis :-



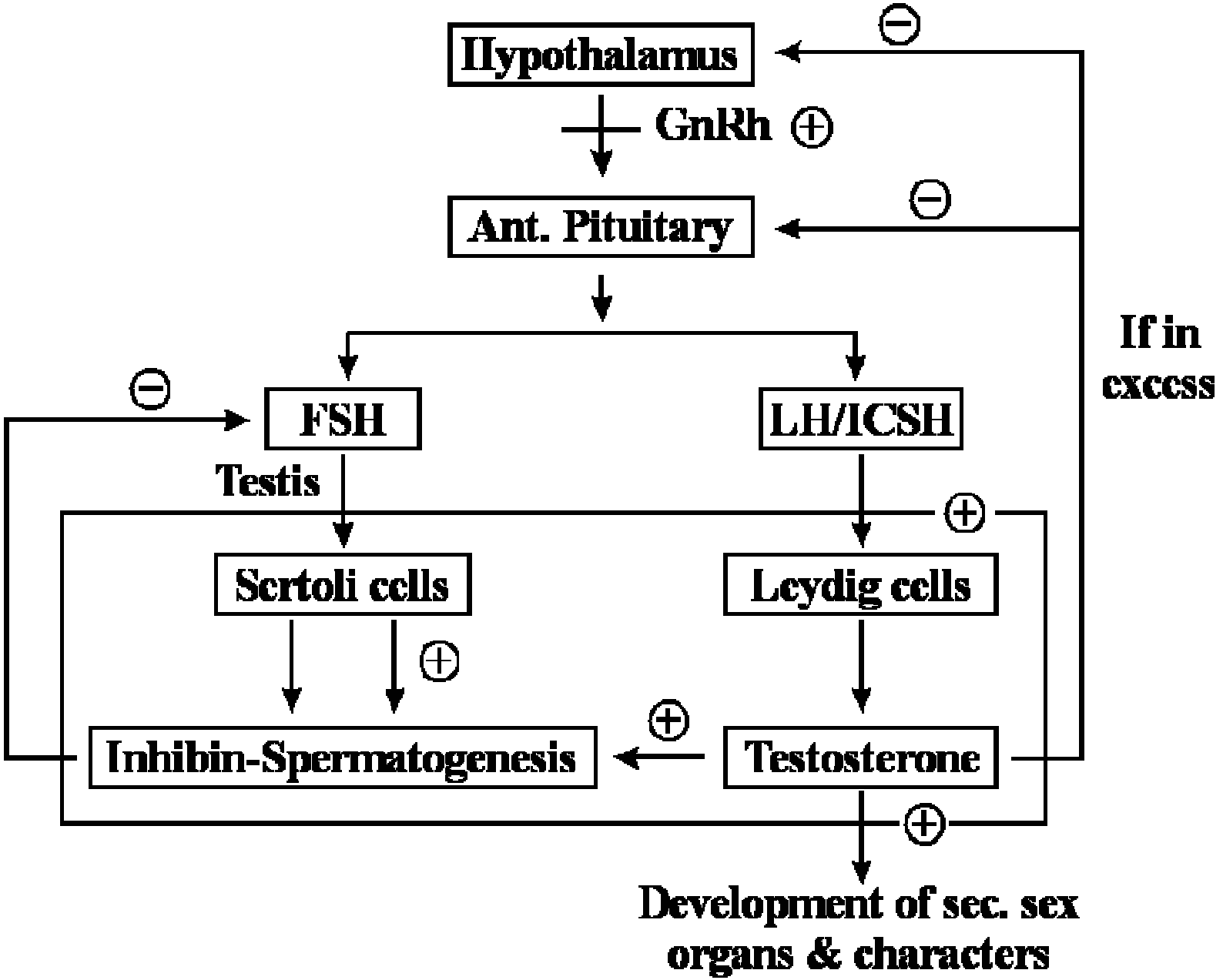
* 1 prim. spermatocyte (2n = 46)
  - → 2 sec. spermatocytes
  - → 4 spermatids
  - → 4 sperms

* 1 Sec. spermatocyte
  - → 2 spermatids
  - → 2 sperms


Plasma membrane
Acrosome
Head
Nucleus containing chromosomal material
Neck
Middle piece
Mitochondria (energy source for swimming)
Tail

- **Human sperm**
  - ✓ Discovery - leeuwenhoek
  - ✓ Motile, flagellated except ascaris
  - ✓ Four parts
    1. Head – acrosome(golgi, hyaluronidase, digest egg membrane) and nucleus
    2. Neck - 2 centrioles(distal – forms basal body for axonema/flagella and proximal- first cleavage division)
    3. Middle piece - mitochondria (power house /energy store) and Axonema (9+2 microtubular)
    4. Tail (longest)-flagella (9+2)
  - ✓ **Note:-** Nebenkern – spirally arranged fused mt.
  - ✓ Manchette – thin cytoplasmic sheath in middle piece

Hormonal Control of Male Reproductive System



- **Disorders :**
  1. ADAM – andropause
  2. Erectile dysfunction – T/t: sildenafil citrate
  3. BPH
  4. Aspermia, azoospermia, oligospermia, asthenozoospermia, teratozoospermia
  5. Inguinal hernia
  6. Hydrocoel
  7. Castration, vasectomy

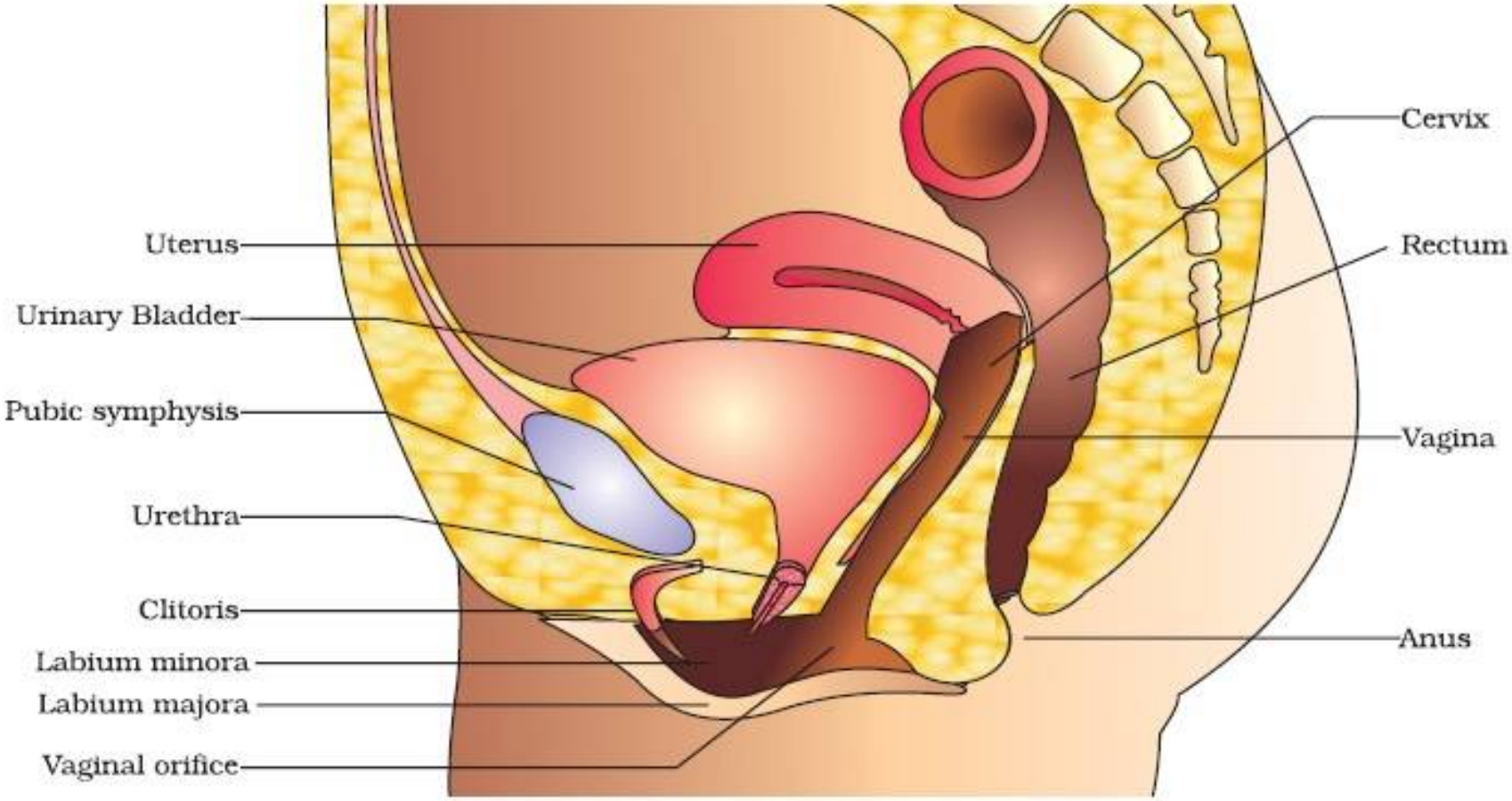


Figure 3.3 (a) Diagrammatic sectional view of female pelvis showing reproductive system

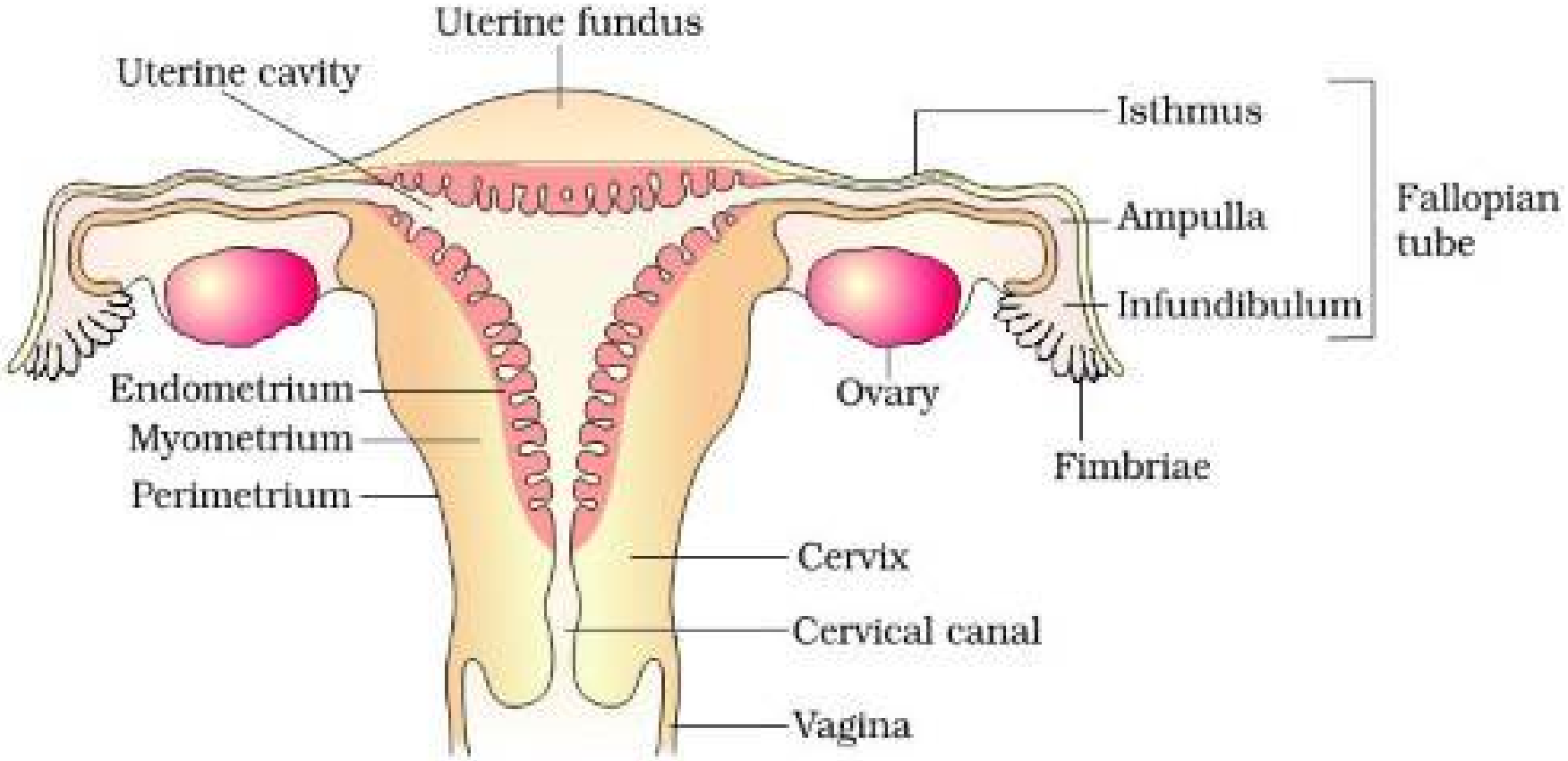


Figure 3.3 (b) Diagrammatic sectional view of the female reproductive system

Female Reproduction System

Primary Sex Organ
- Ovary

Sec. Sex Organs (=Genital duct)
- F.T.
- Uterus
- Cervix
- Vagina

External Genitalia
- Mons pubis
- Clitoris
- Vestibule
- Labia

♀ Reproductive Glands

MBS
- Mammary
- Bartholin
- Skene gland

Exercise of maths & Chemistry are Very Lengthy

- **Female reproductive system**

1) Ovary - primary female sex organ, produce gamete (ovum) and steroid ovarian hormones
   - ✓ Inside lower abdominal/ pelvic cavity
   - ✓ 2-4 cm length, almond shaped
   - ✓ Germinal epithelium - outside surface of ovary, simple cuboidal cells – oogonia (diploid)
   - ✓ Ovarian stroma (cortex – ovarian follicles in various stages and medulla – blood vessels, nerves)
2) Fallopian tube/ uterine tube/ oviducts/ salpinges - passage of eggs/ zygote from ovary to uterus, site for fertilization, 10-12cm long

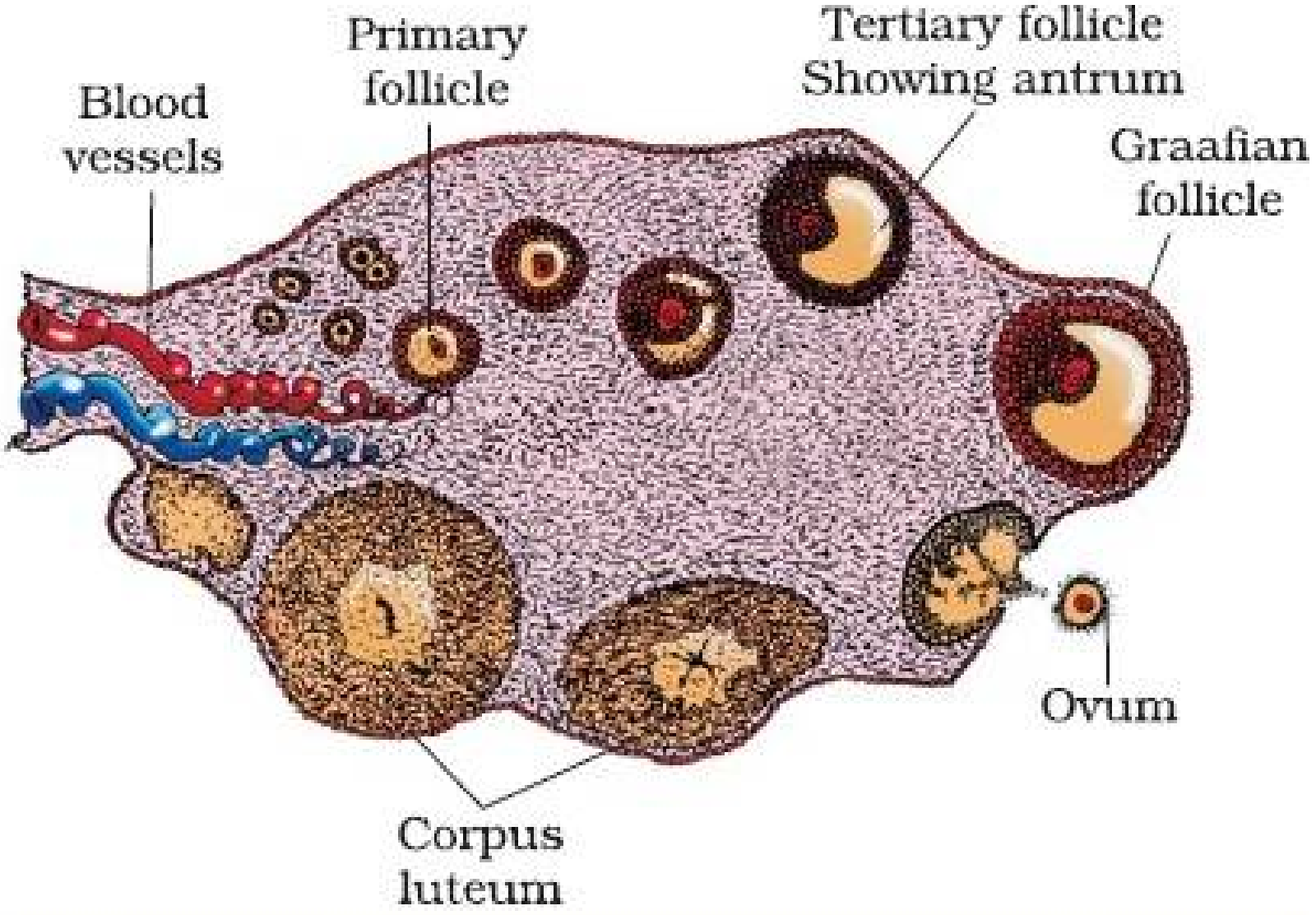


Figure 3.7 Diagrammatic Section view of ovary

- **Four parts –**
  1. Infundibulum – funnel shaped, close to ovary, fimbriae, ostium
  2. Ampulla – widest, longest
  3. Isthmus – Has narrow lumen
  4. Intramural/ interstitial
     - ✓ Fertilization site – ampullary - isthmic junction
     - ✓ Internally 3 layers – serosa, muscular, ciliated columnar epithelium (kinocilia)

3) Uterus /womb/ hystera – inverted pear, between bladder and rectum
   - ✓ Supported by ligaments attached to pelvic wall
   - ✓ Three parts – fundus, body, Cervix (opens into vagina, cervical canal, external and internal os)
   - ✓ cervical canal + vagina = birth canal
   - ✓ Wall of uterus – three layers (perimetrium, myometrium – parturition, endometrium – glandular, undergoes cyclical changes during menstrual cycle)
   - ✓ Decidua – endometrium in pregnancy

Decidua-3 Layers

[Protects Embryo from mothers immune system]

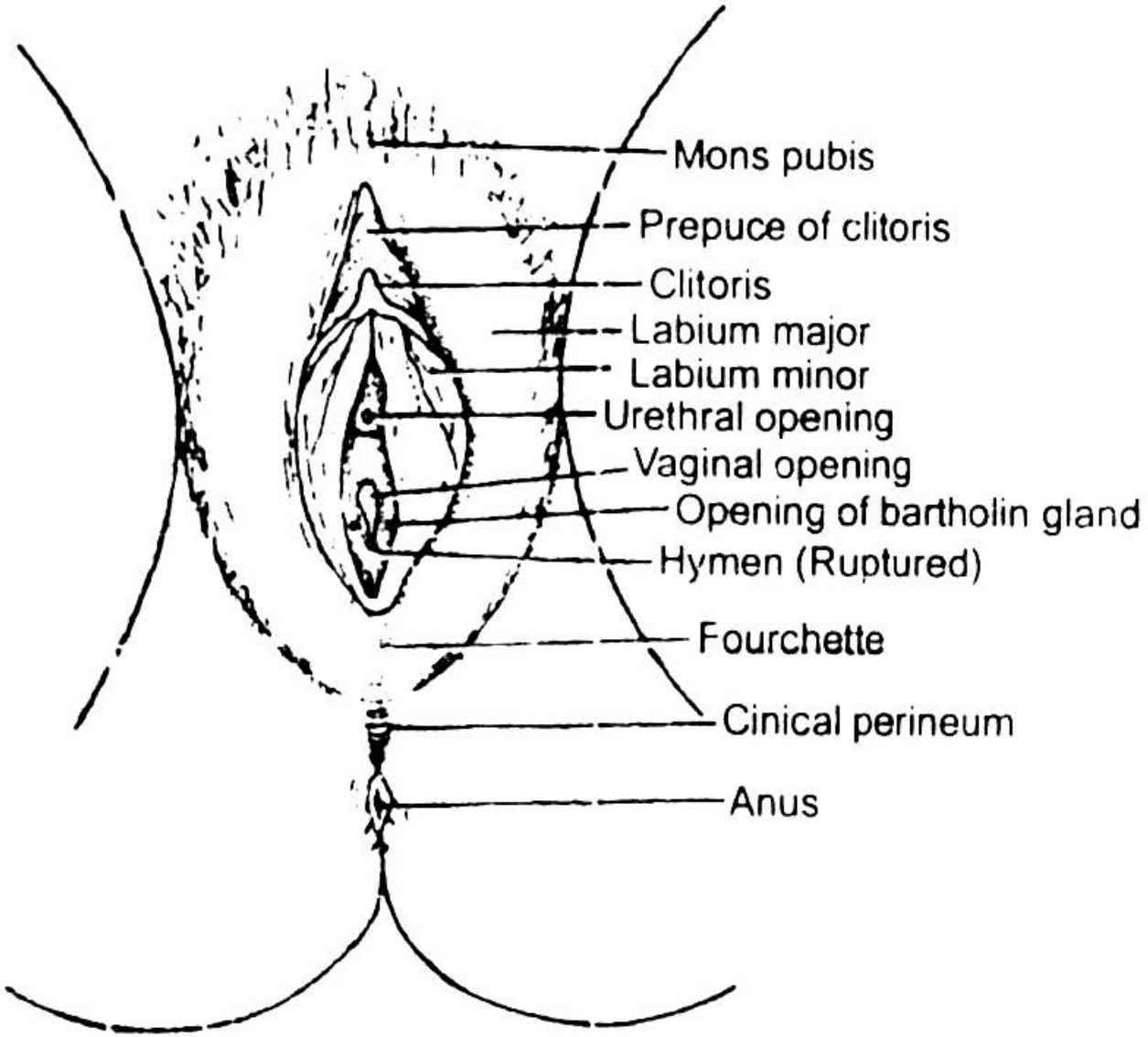
1) D. Parietalis/ D.vera
– no relation with embryo

2) D. placentalis/ D. basalis
– Contributes in Placenta formation

3) D. Capsularis
– Surround Embryo from all sides till 26 wks of pregnancy

4) Vagina-
   - ✓ 7.5-10 cm long, NKSSE, no glands, lactobacillus, acidic pH, copulatory organ, birth canal

- Hymen – membrane covering partially opening of vagina
  - ✓ Often torn during first coitus, also can be broken by a sudden fall or jolt, insertion of vaginal tampon, horse riding, cycling etc
  - ✓ In some women, persist even after coitus
  - ✓ Presence or absence of hymen is not a reliable indicator of virginity or sexual experience

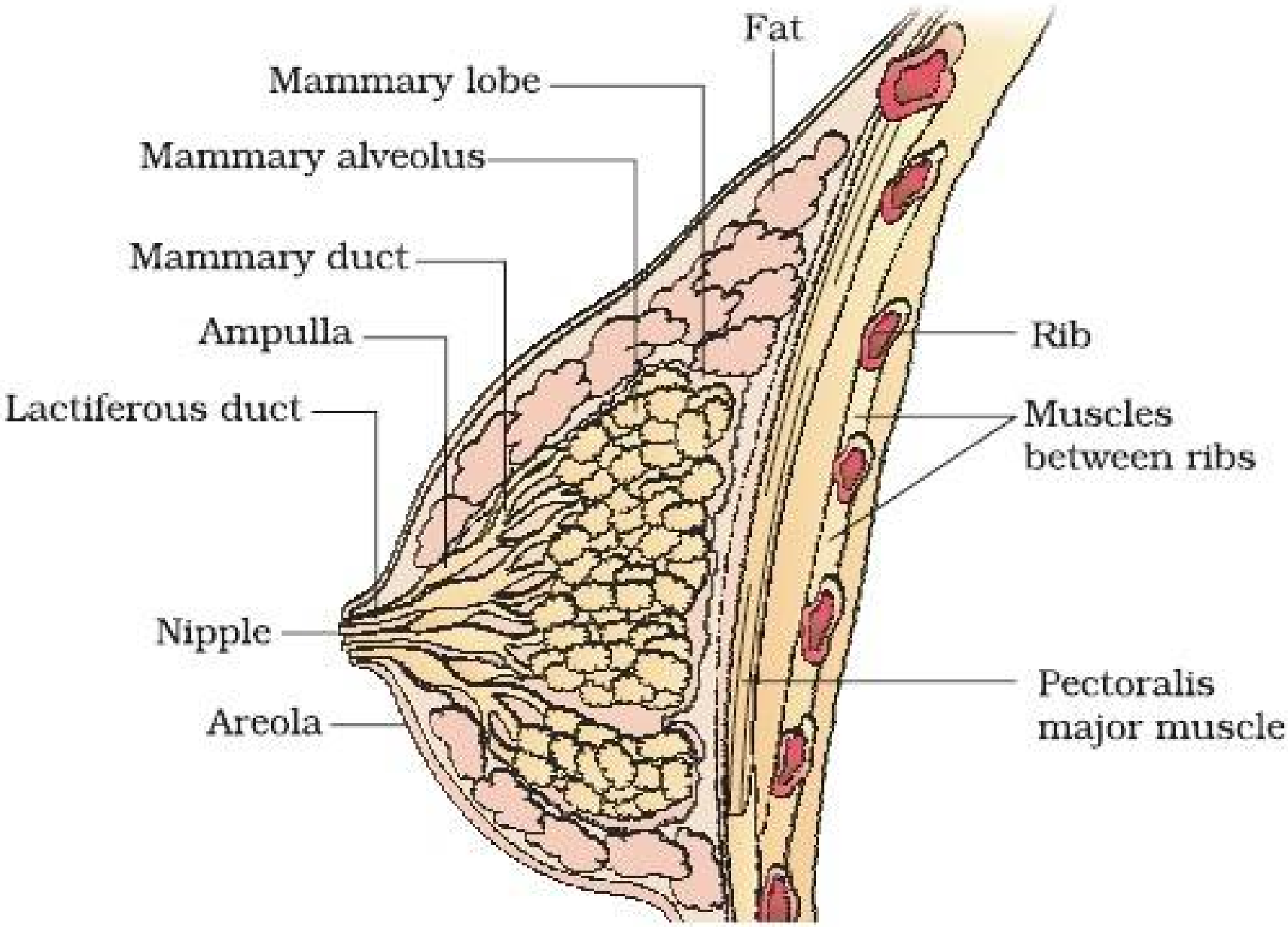


The external genitalia in the female

- **Vulva/external genitilia –**
  - ✓ 2 openings – vaginal and urethral (vestibule - bowl shaped cavity)
  - ✓ Mons pubis – cushion of fatty tissue, covered by skin and pubic hair
  - ✓ Labia majora – fleshy folds of tissue (skin, extent down from mons pubis and surround vaginal opening)
  - ✓ Labia minora – paired folds of tissue under labia majora, tip – prepuce
  - ✓ Clitoris – tiny finger like, at upper junction of two labia minora above urethral opening, erectile tissue for pleasure sensation
  - ✓ Fourchette- folds of skin at posterior junction of labia minora
  - ✓ Perineum – area between fourchette and anus

- **Female reproductive glands –**
  1. Bartholin glands – one pair , each side vaginal opening, mucoid alkaline secretion, lubricates and reduce acidity of vagina
  2. Glands of skene/peri/para-urethral glands – several, around urethral opening, lubricates and reduce acidity of vagina and vestibule

- **Mammary glands -**
  - ✓ Characteristics feature of all female mammals, develops at puberty, paired
  - ✓ SAT- modified sweat gland, apocrine, tubulo – alveolar gland
  - ✓ Contains glandular tissue and fat (determine size of breast)
  - ✓ Glandular tissue of each breast – 15-20 mammary lobes – cluster of milk secreting cells (alveoli), milk stored in cavities (lumen) of alveoli – opens into mammary tubule – the tubules of each lobe joins to forms mammary duct – several mammary ducts join to form a wider mammary ampulla/ lactiferous sinus connected to lactiferous duct, through which milk is sucked out
  - ✓ Note:- mammary ampulla – temporary storage of milk
  - ✓ Areola – dark pigmented area around nipple


Fat
Mammary lobe
Mammary alveolus
Mammary duct
Ampulla
Lactiferous duct
Nipple
Areola
Rib
Muscles between ribs
Pectoralis major muscle

- ✓ Hormonal control –
  1. Thelarche –at puberty, estrogen
  2. Progesterone – multiplication of milk alveoli
  3. Prolactin – milk production
  4. Oxytocin – milk ejection / milk- let down hormone
  5. Human placental lactogen (hPL)- production of milk during pregnancy

Passage of Milk

Many alveoli

↓

Many mammary tubules

↓

One mammary duct (15-20 in each gland)

↓

One Lactiferous Sinus/Mammary Ampulla
(15-20 in each gland)
(Dilated part, just before nipple)
Temporary milk storage

↓

One Lactiferous Duct (15-20 in each gland)

↓

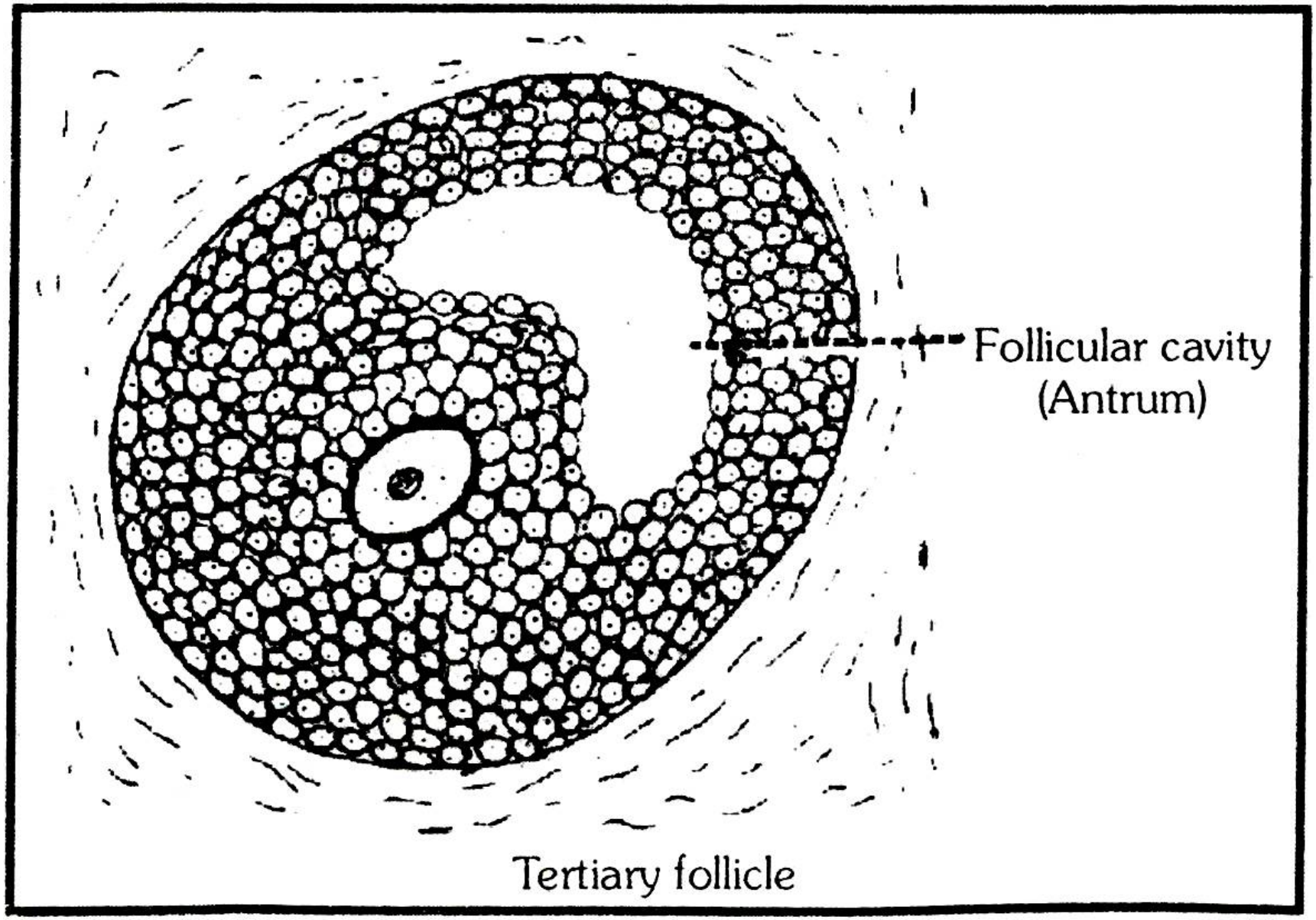
Opens outside through nipple

- Follicle development inside ovary (cortex of stroma)
  1. Primordial follicle – primary oocyte, surrounded by single layer of squamous stromal cells
  2. Primary follicle - primary oocyte surrounded by single layer of cuboidal stromal/ granulosa cells
     - ✓ At birth : 2-4 million /ovary
     - ✓ At puberty: 60000 - 80000/ovary
     - ✓ Formed in fetal life, before birth
  3. Secondary follicle – primary oocyte surrounded by multiple layers of granulosa/ follicular cells and a new theca layer (fibrous)

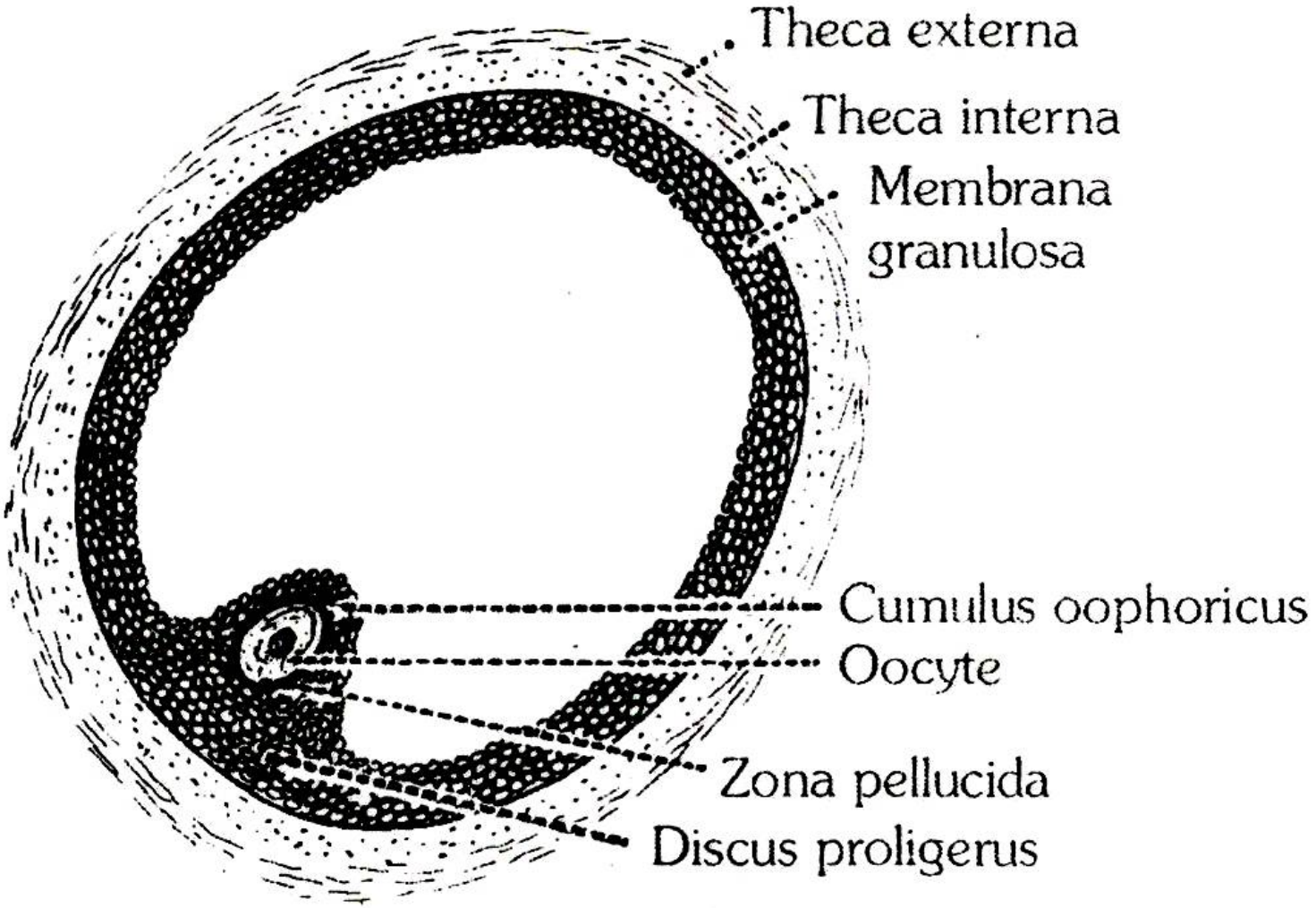
4. **Tertiary follicle –**

   Fluid filled cavity /antrum, theca interna and externa organized, primary oocyte grows in size and completes its first meiotic division (unequal – haploid large secondary oocyte and tiny first polar body formed, secondary oocyte secretes zona pellicuda (glycoprotein, non- cellular membrane surrounding secondary oocyte)

   Note:- theca interna – glandular, secretary – androgen formation – granulosa cells (aromatization of androgen into estrogen)


Follicular cavity
(Antrum)
Tertiary follicle

5. Graafian follicle- most ripened, mature follicle
   - ✓ Antrum surrounding oocyte divides granulosa cells into cumulus oophorus (cluster of cells around sec.oocyte) and membrana granulosa
   - ✓ Discus proligerus/ germ hill – connects sec.oocyte with wall of follicle
   - ✓ Zona pelucida, T.externa and interna, liquor follicle all present
   - ✓ Corona radiata – innermost cells of cumulus oophorus, surrounding zona pelicuda



Graafian follicle

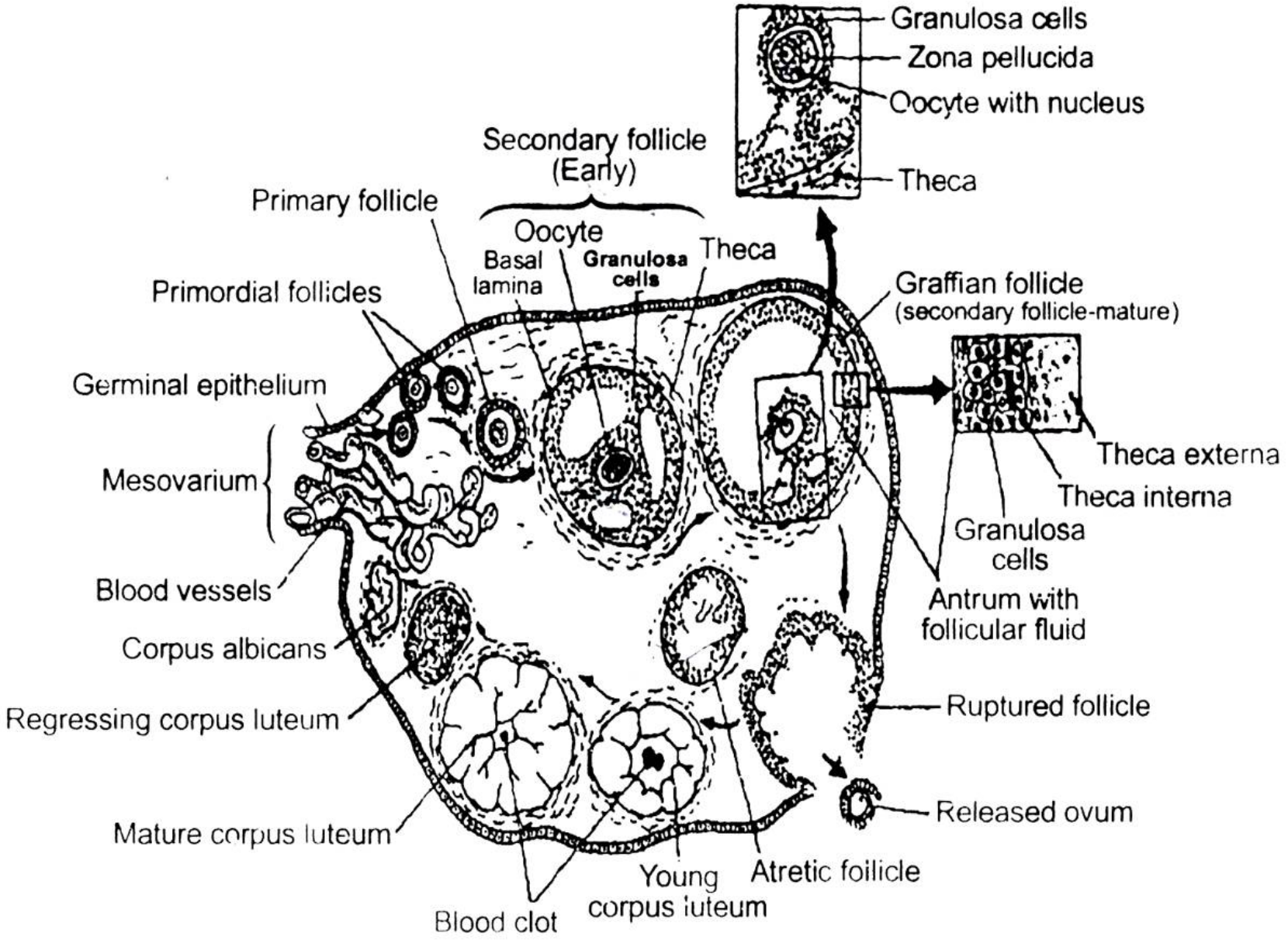
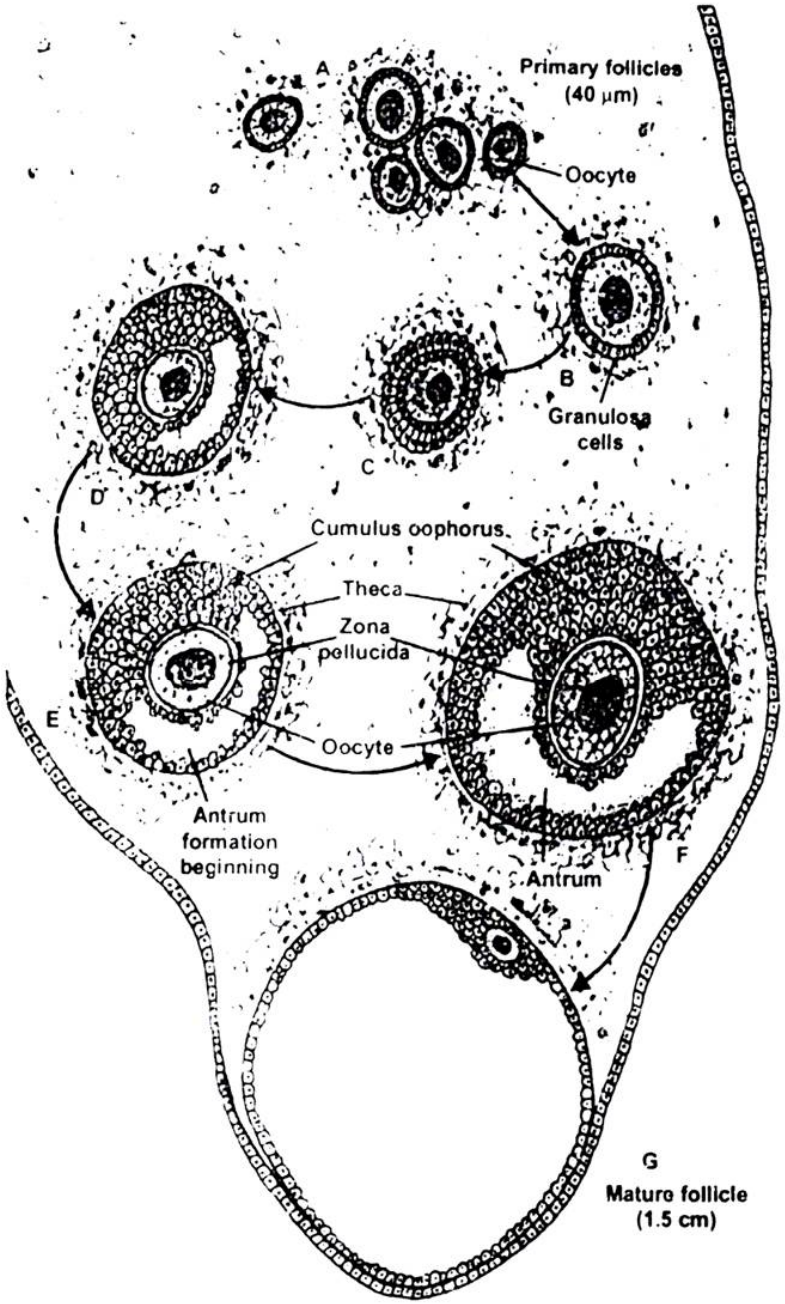


Fig. : A section of human ovary



A : Primary follicle

B : Growing primary follicle

C : Secondary follicle

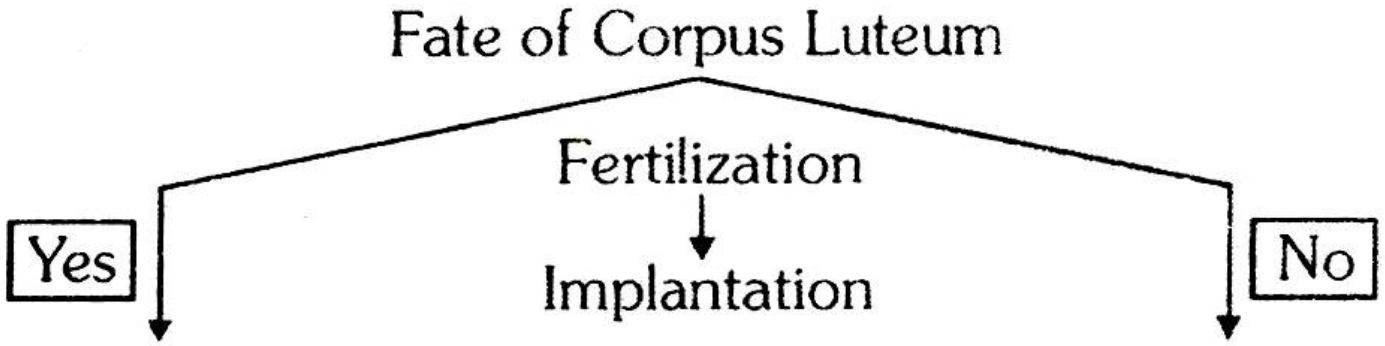
D : Tertiary follicle

E and F : Growing tertiary follicle showing antrum

G : Graafian follicle

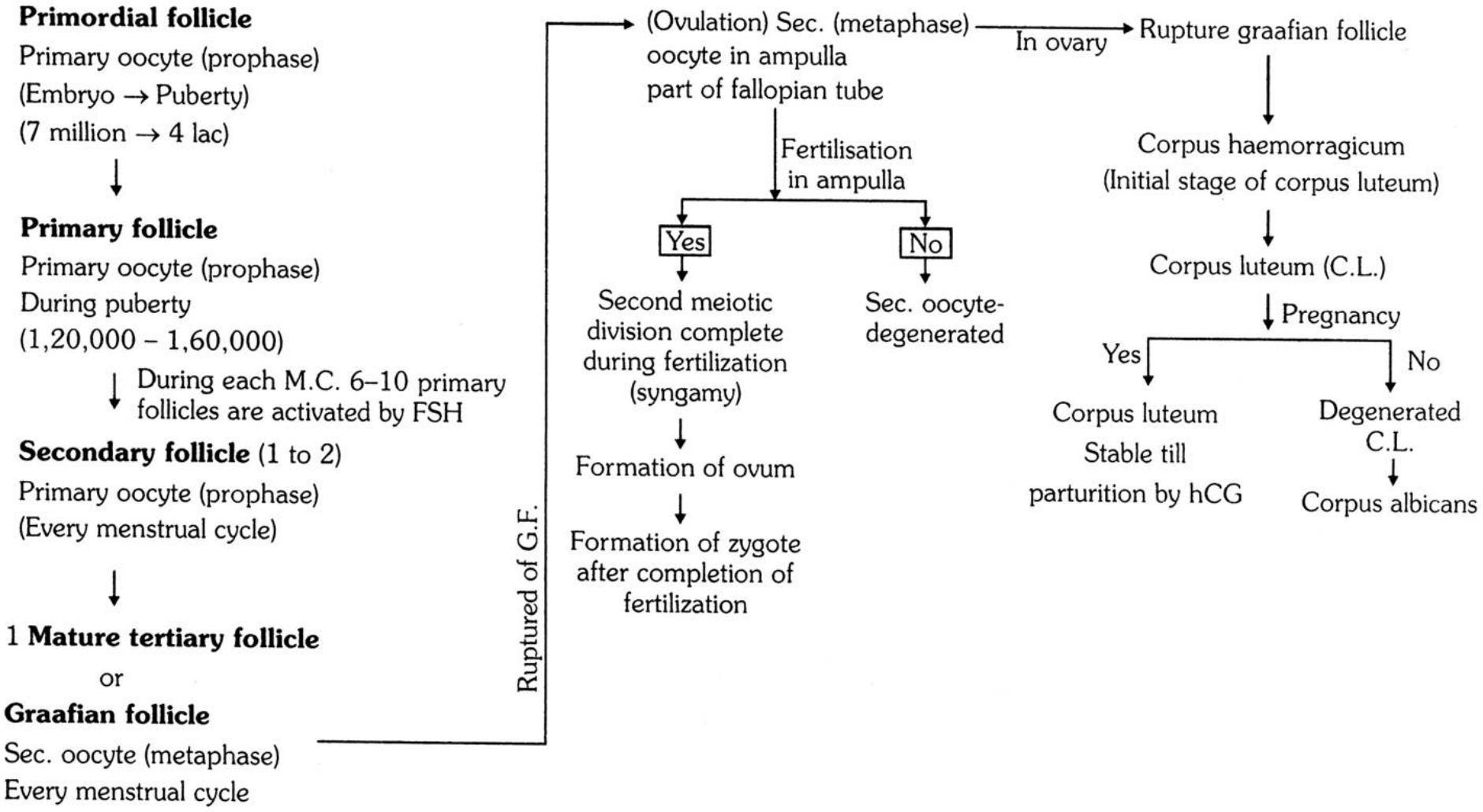
Fig. : Development of a human oocyte and ovarian follicle

- Ovulation – rupture of graafian follicle to release secondary oocyte/ ovum form ovary (alongwith zona pellucida and corona radiata)
- Corpus luteum – yellow/ transformed graafian follicle after ovulation, glandular
  - ✓ Secretes progesterone (essential for maintenance of endometrium), little estrogen, relaxin, inhibin
- Corpus albicans – white, non- glandular, degenerates if no fertilization



Corpus luteum
become stable for next
nine months by the help
of hCG secreted by itself
embryonic cells trophoblast

Corpus luteum
start degenerating
after about 9 days
of its formation
i.e. about 23rd day of m.c.
Degenerated C.L. is known
as corpus albicans


Primordial follicle
Primary oocyte (prophase)
(Embryo → Puberty)
(7 million → 4 lac)
Primary follicle
Primary oocyte (prophase)
During puberty
(1,20,000 – 1,60,000)
During each M.C. 6–10 primary follicles are activated by FSH
Secondary follicle (1 to 2)
Primary oocyte (prophase)
(Every menstrual cycle)
1 Mature tertiary follicle
or
Graafian follicle
Sec. oocyte (metaphase)
Every menstrual cycle
Ruptured of G.F.
(Ovulation) Sec. (metaphase) oocyte in ampulla part of fallopian tube
Fertilisation in ampulla
Yes
No
Second meiotic division complete during fertilization (syngamy)
Sec. oocyte-degenerated
Formation of ovum
Formation of zygote after completion of fertilization
In ovary
Rupture graafian follicle
Corpus haemorragicum
(Initial stage of corpus luteum)
Corpus luteum (C.L.)
Pregnancy
Yes
No
Corpus luteum
Stable till
parturition by hCG
Degenerated C.L.
Corpus albicans

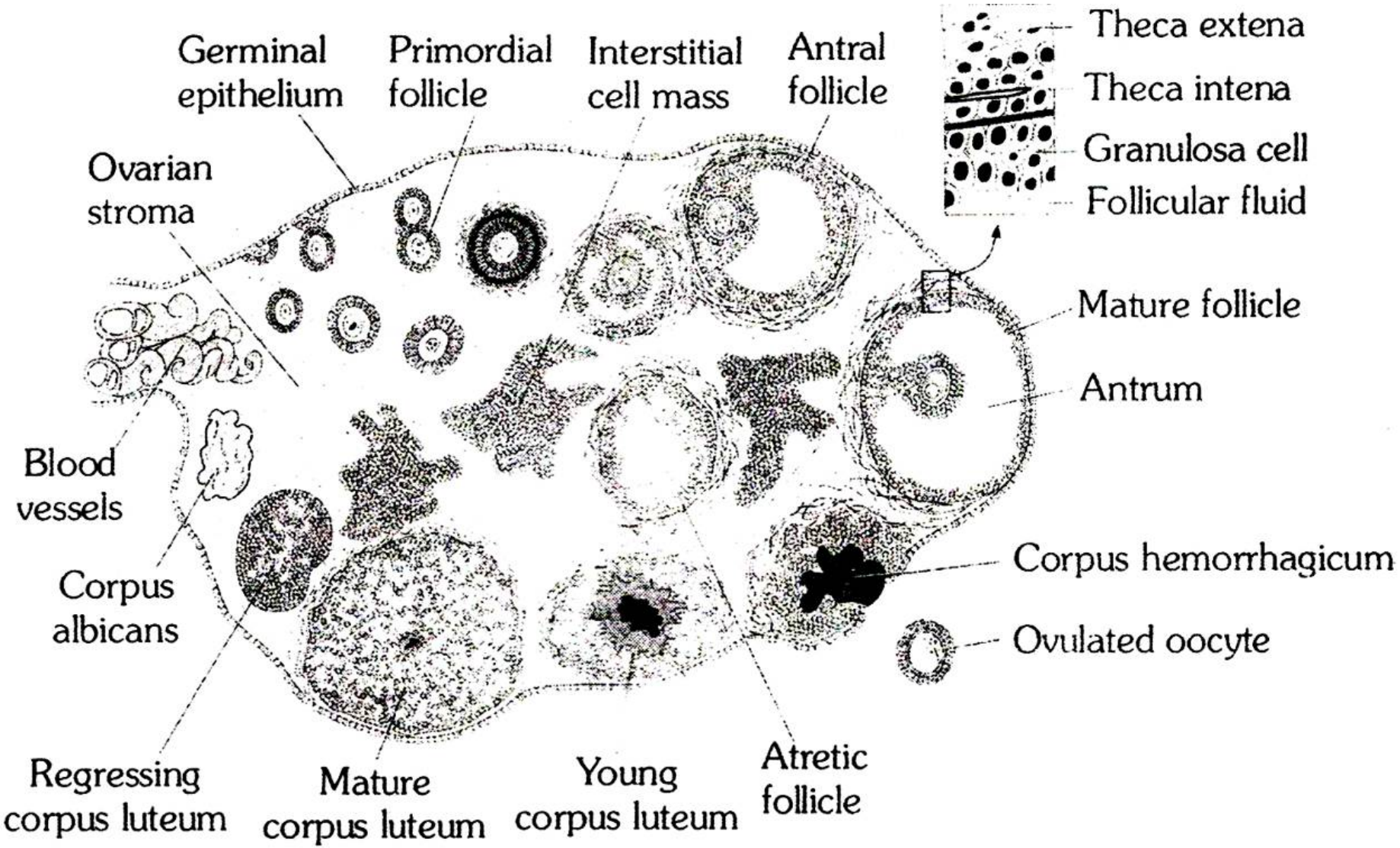


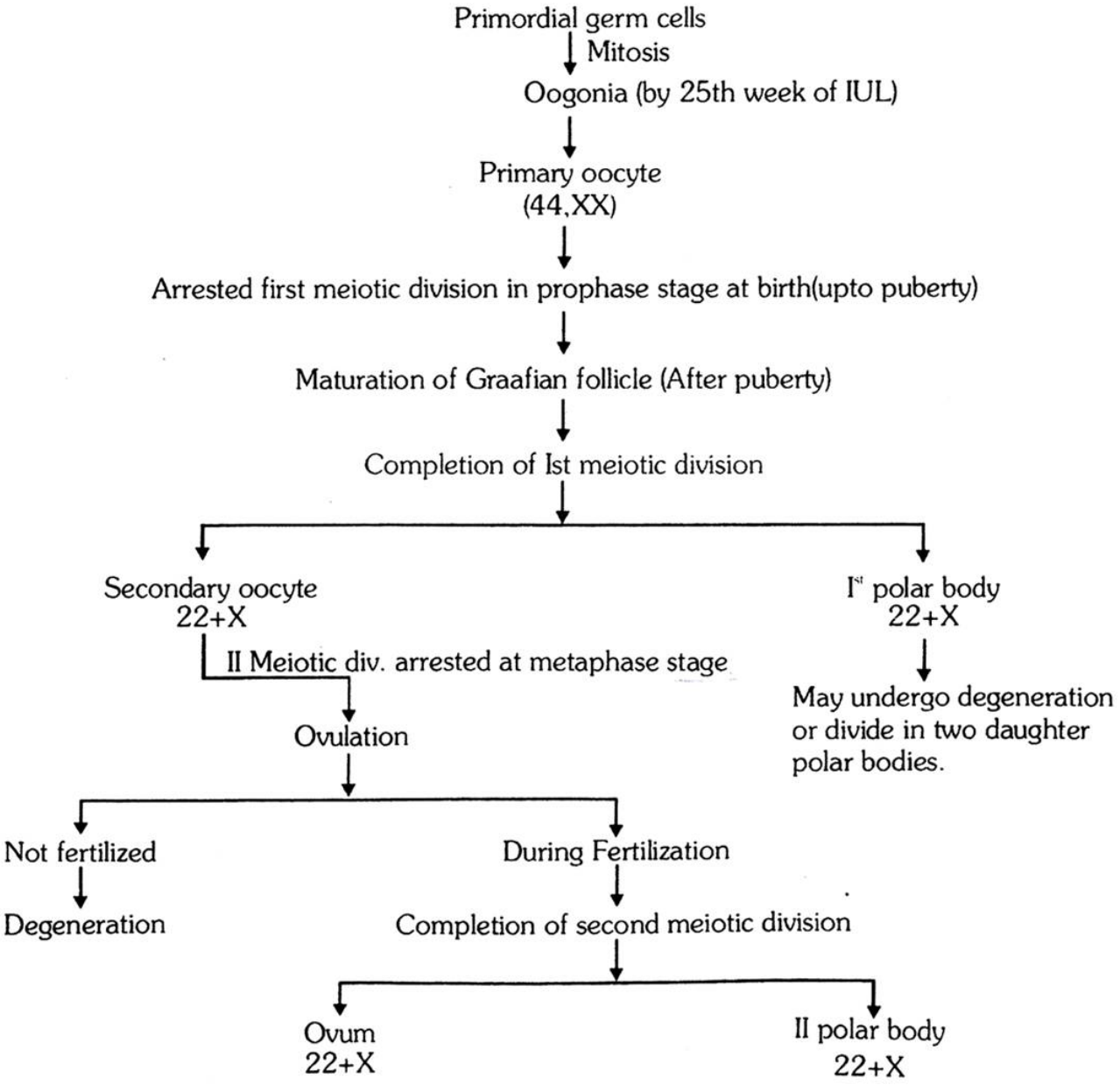
Diagram of a mammalian ovary

- Oogenesis – formation of mature female gamete/ ovum/ ootid
  - ✓ Germ cells – extragonadal (extra-embryonic mesoderm, yolk sac)
  - ✓ Starts before birth (in-utero) from second month of pregnancy
  - ✓ Completes only after fertilization

Three phase -

1. Multiplication – completed before birth, no multiplication after birth, germ cells – mitosis – produce daughter oogonia (2n)
   - ✓ Oogonia arrested in diplotene of prophase – I of meosis – I (called primary oocyte – 2n)
   - ✓ At birth – 2million /20 lakh primary follicles in each ovary

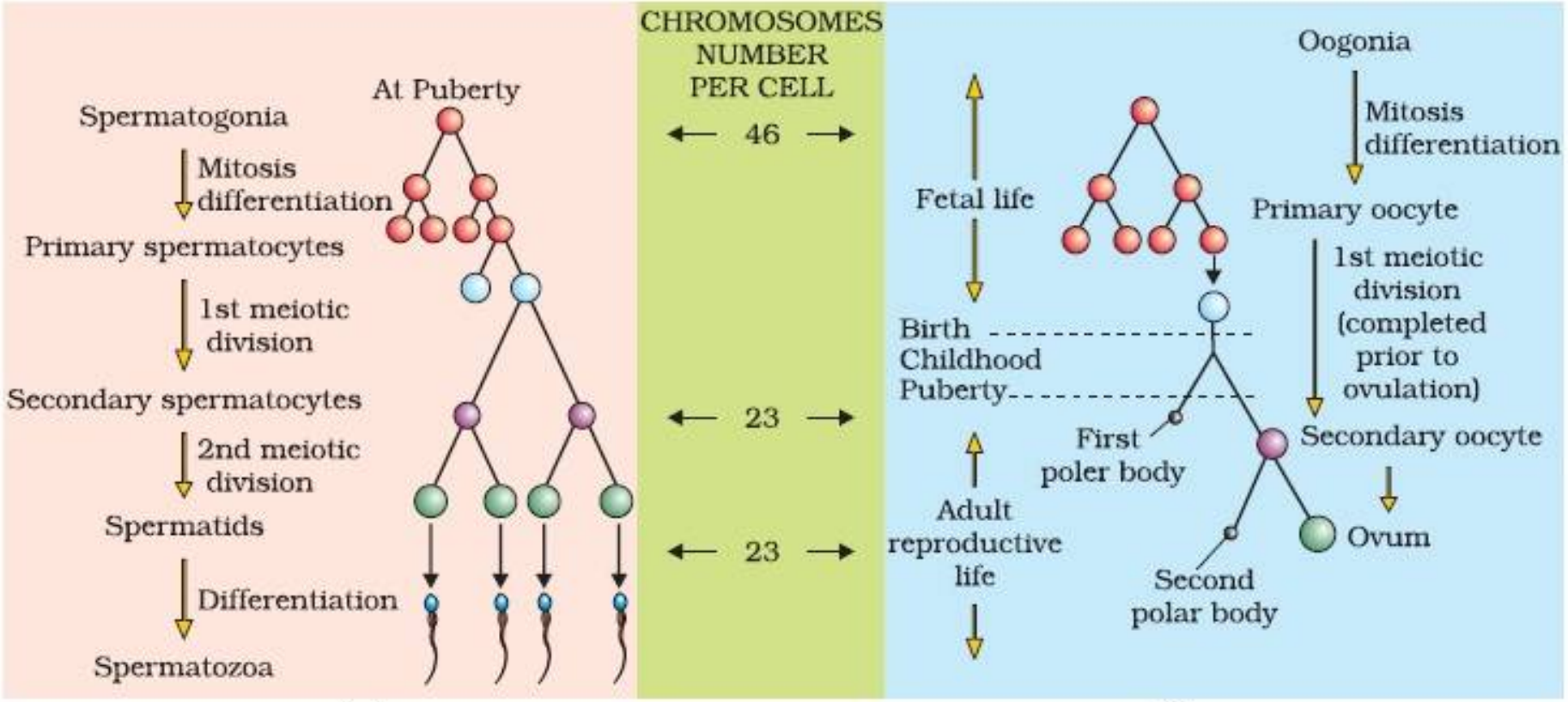
OOGENESIS


Primordial germ cells
Mitosis
Oogonia (by 25th week of IUL)
Primary oocyte
(44,XX)
Arrested first meiotic division in prophase stage at birth(upto puberty)
Maturation of Graafian follicle (After puberty)
Completion of Ist meiotic division
Secondary oocyte
22+X
I st polar body
22+X
II Meiotic div. arrested at metaphase stage
May undergo degeneration
or divide in two daughter
polar bodies.
Ovulation
Not fertilized
During Fertilization
Degeneration
Completion of second meiotic division
Ovum
22+X
II polar body
22+X

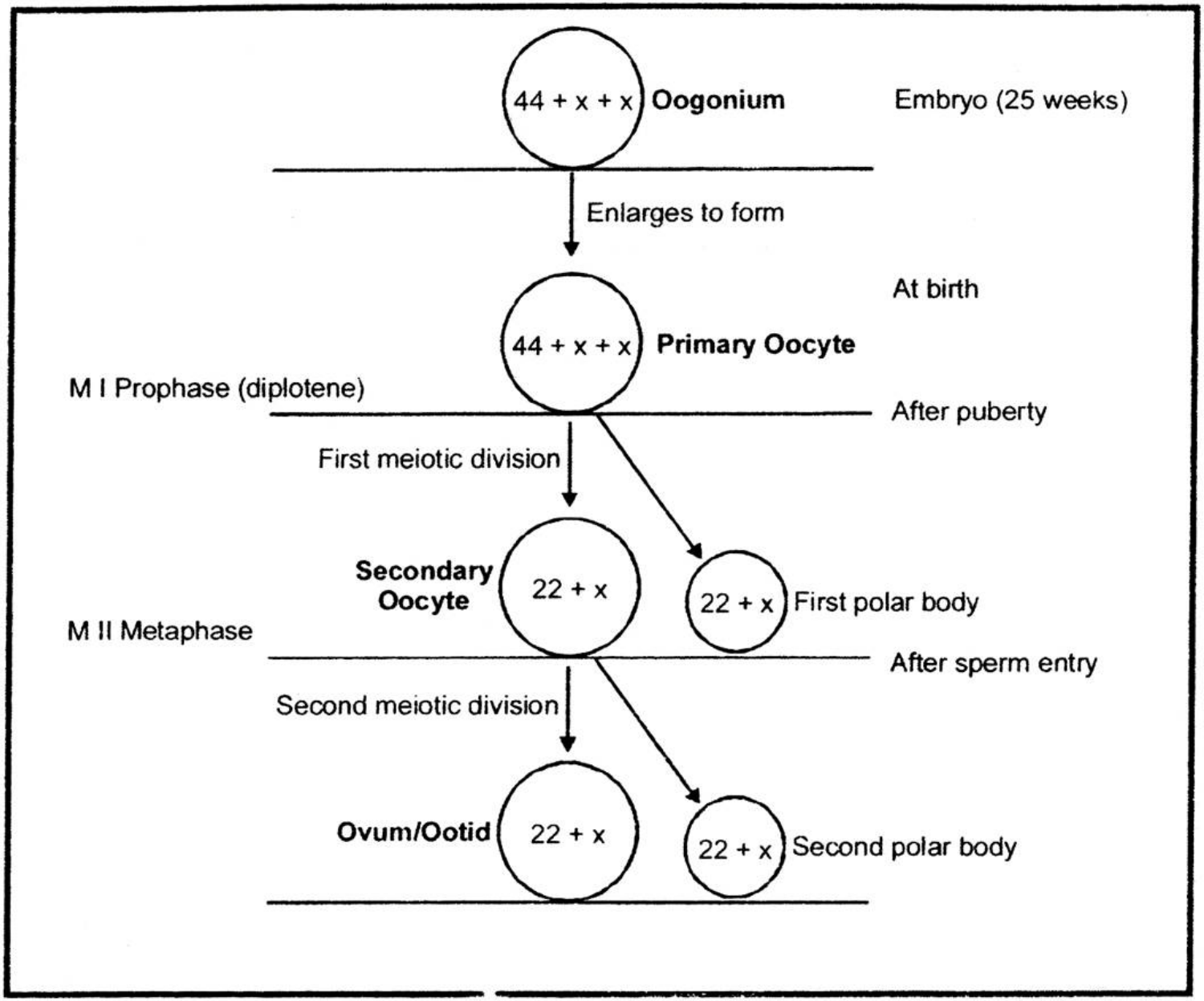
2. Growth phase- longest
   - ✓ Starts from birth till start of puberty, follicular atresia occurs
   - ✓ At start of puberty – 60000 to 80000 primary follicles in each ovary
3. Maturation phase – due to rise in GnRH and FSH
   - ✓ Every month – one primary oocyte completes meiosis-I (unequal cytokinesis) to produce one secondary oocyte (n) (arrested at metaphase-II of meiosis-II)
   - ✓ Secondary follicle – 1-2/month/ovary
   - ✓ Tertiary and graafian follicle – 1/month/ ovary
   - ✓ 12 secondary oocyte produced every year till menopause (maximum 500 in complete reproductive life)

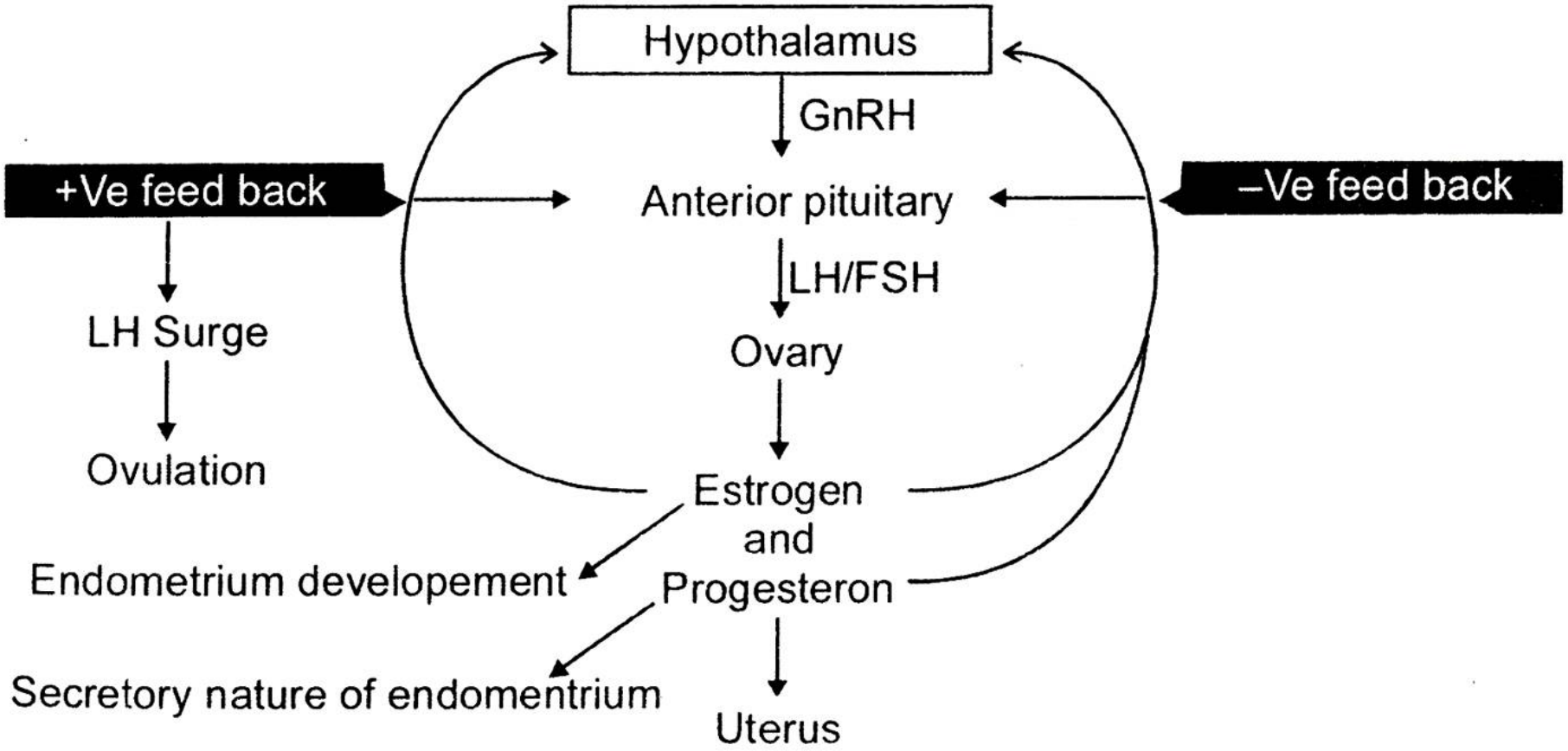
Ovulation :

- ✓ Secondary oocyte enters into FT from ovary, completes meiosis-II only if fertilization occurs
- ✓ 1 oogonia – one ovum and 2-3 polar body
- ✓ 1 primary oocyte – one secondary oocyte (and 1 polar body) – one ovum + one polar body
- ✓ One primary oocyte – one ovum + 2 - 3 polar body
- ✓ Fraternal/ unidentical twins – 2 follicles mature simultaneously
- ✓ Note :- 25 ovum produced by 25 oogonia/ primary/ secondary oocyte


At Puberty
Spermatogonia
Mitosis differentiation
Primary spermatocytes
1st meiotic division
Secondary spermatocytes
2nd meiotic division
Spermatids
Differentiation
Spermatozoa
CHROMOSOMES NUMBER PER CELL
46
23
23
Oogonia
Mitosis differentiation
Fetal life
Primary oocyte
1st meiotic division (completed prior to ovulation)
Birth
Childhood
Puberty
First poler body
Secondary oocyte
Adult reproductive life
Ovum
Second polar body

(a) (b)


44 + x + x
Oogonium
Embryo (25 weeks)
Enlarges to form
At birth
44 + x + x
Primary Oocyte
M I Prophase (diplotene)
After puberty
First meiotic division
Secondary Oocyte
22 + x
22 + x
First polar body
M II Metaphase
After sperm entry
Second meiotic division
Ovum/Ootid
22 + x
22 + x
Second polar body


Hypothalamus
GnRH
+Ve feed back
Anterior pituitary
–Ve feed back
LH/FSH
LH Surge
Ovary
Ovulation
Estrogen
and
Progesteron
Endometrium developement
Secretory nature of endomentrium
Uterus

BRIEF REVIEW

Development of secondary sex organ -

Male	Female
• Wolffian duct or Mesonephric duct – Epididymis, Vas deferens, Seminal vesicle	• Mullerian duct – Fallopian tube, uterus and vagina (Oviduct)

Homologus Organs

	Female	Male
1.	Labia Majora	Scrotum
2.	Labia minora	Penile Urethra
3.	Clitoris	Penis
4.	Bartholin gland	Cowper’s
5.	Glands of Skene	Prostate

- **Menstrual cycle :**
  - ✓ Reproductive cycle in female primates (monkeys, apes, human beings)
  - ✓ Menarche – first menstruation, at puberty
  - ✓ Duration – 28/29 days
  - ✓ One ovum is released (ovulation) during middle of each menstrual cycle
  - ✓ Menstruation only occurs if released ovum is not fertilized
  - ✓ Lack of menstruation may be indicative of pregnancy, stress, poor health etc
  - ✓ Regulation by pituitory (FSH and LH) and ovarian hormones (estrogen and progesterone)

Four phases

1. Menstrual phase (day 1-5) – cycle starts , lasts for 3-5 days, menstrual flow due to break down of endometrial lining uterus and its blood vessels (forms liquid – comes out through vagina)
   - ✓ Due to low level of estrogen and progesterone
2. Follicular /proliferative phase (day 6-13)
   - ✓ Gonadotropins (LH and FSH) increase gradually – stimulates follicular development in ovary and secretion of estrogen by growing follicles
   - ✓ Rise in estrogen – rebuilding of endometrium
   - ✓ Both LH and FSH attain peak in middle of cycle (day 14)

3. Ovulation/ ovulatory phase - day14
   - ✓ LH surge (rapid secretion to its max. level) – rupture of graafian follicle – release of secondary oocyte/ ovum
4. Luteal / secretory phase – day 15 -28
   - ✓ Fixed duration (day of ovulation = duration of m.c-14)
   - ✓ Formation of CL (under LH) from remaining parts of graafian follicle
   - ✓ CL secretes progesterone, E2, relaxin , inhibin
   - ✓ CL is maintained by LH
   - ✓ Progesterone –makes endometrium glandular/ secretary (necessary for implantation of fertilized ovum)
   - ✓ Absence of fertilization – CL degenerated, disintegration of endomatrium – menstruation (new cycle begins)

- Menstrual phase – due to decreased progesterone and estrogen
- Proliferative – increased estrogen
- Secretory- increased progesterone
- Follicular – increased FSH
- Luteal – increased LH
- Ovulation – increased LH
  - ✓ FSH and LH peak – day 12-14
  - ✓ Progesterone begins to form from day 15 and peak at day 21
  - ✓ estrogen (2 peaks) - Follicular and luteal phase
  - ✓ Menopause - ceasation of M.C, around 50 years of age
  - ✓ amenorrhoea, oligomenorrhoea, polymennorrhoea, menorrhagia, dysmenorrhoea
  - ✓ Normal blood flow: 40 – 80 ml (upto 100 ml)
  - ✓ precocious puberty – menarche before 8 years of age
  - ✓ cyclic menstruation is an indicator of normal reproductive phase and extents between monarchy and menopause

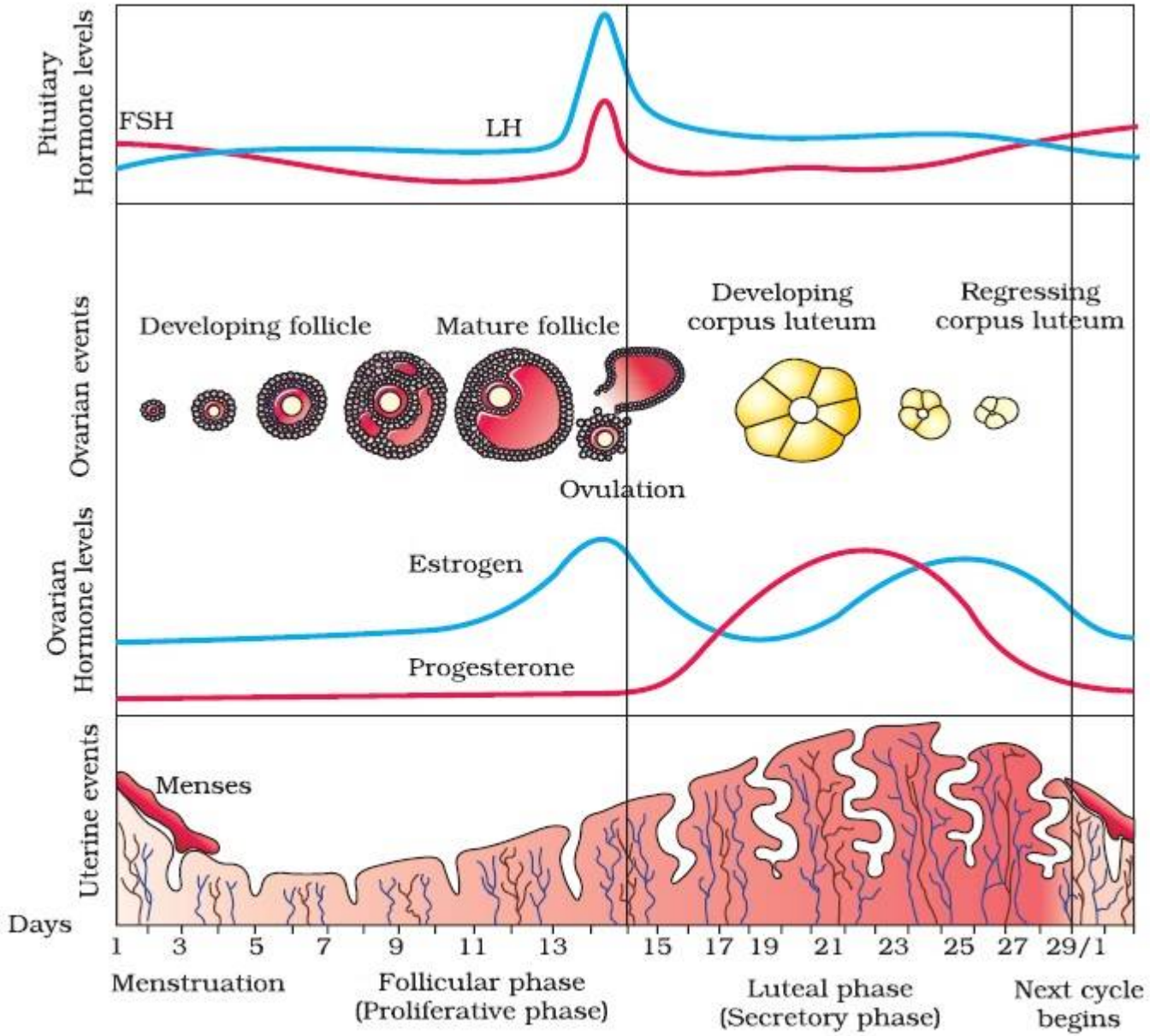
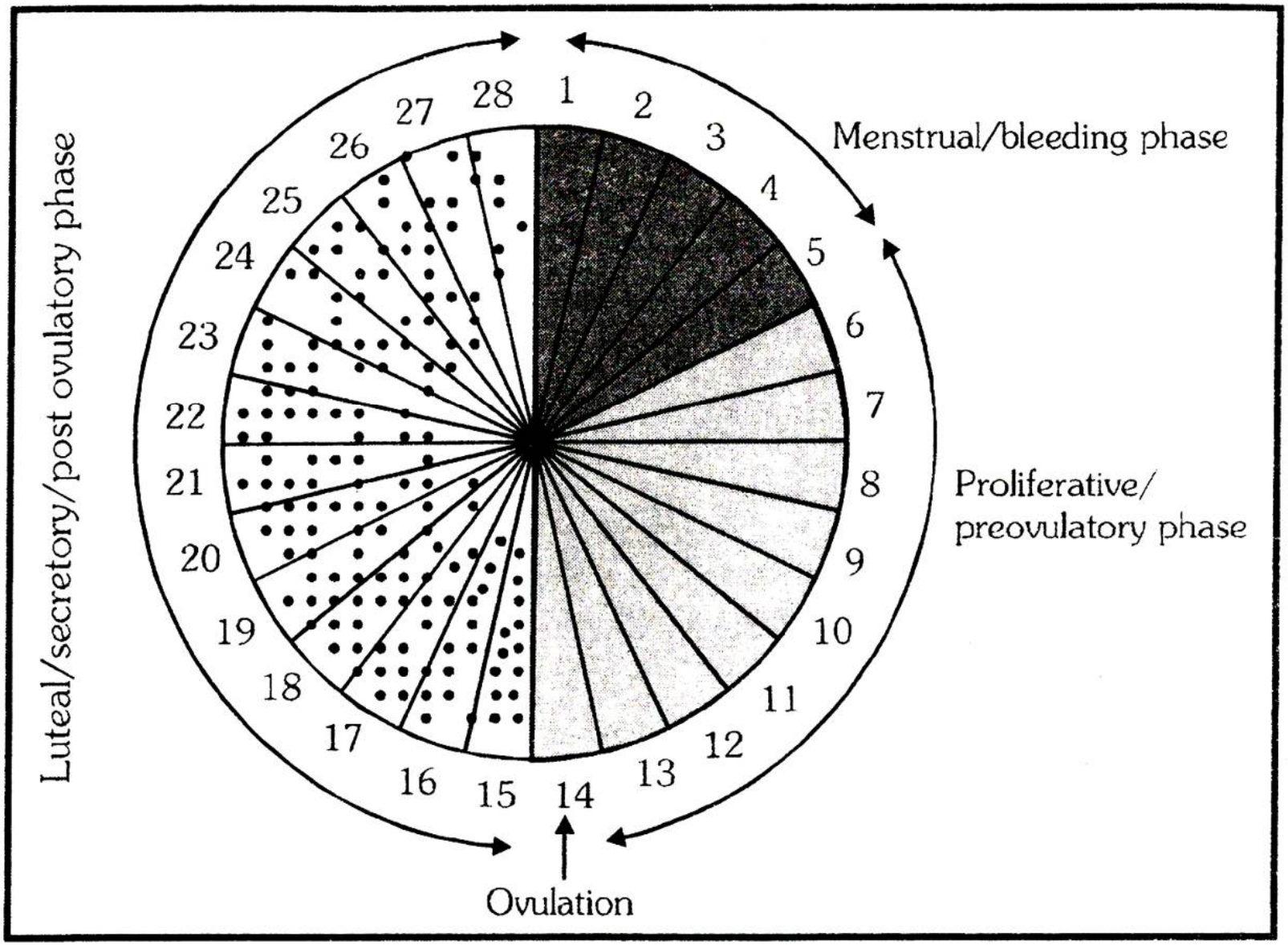


Figure 3.9 Diagrammatic presenation of various events during a menstrual cycle

MENSTRUAL CYCLE

Duration – 28 days Ideally (Range - 22 to 32 days)



	Estrogen		Progesterone
1.	Endometrial hyperplasia	1.	Increase secretory nature of endometrium (Development of glands)
2.	Increase vascularity of endometrium (Uterine arteriole become tortous)	2.	Increase adhesive nature of endometrium
3.	Myometrial hypertrophy.	3.	Decrease myometrial contraction.
4.	Ultimately increase thickness of uterine wall.	4.	Maintain thickness of uterine wall.

- Estrous cycle (non- primate mammals)
  - ✓ no bleeding /menstruation
  - ✓ Copulation occurs only during estrous phase/ heat period due to increased estrogen
- Insemination – release of semen by penis into vagina of female
- Fertilization -
  - ✓ Fusion of male and female gamete (sperm with an ovum)
  - ✓ Plasmogamy, karyogamy, amphimixis
  - ✓ Site - ampullary region of FT (ampullary - isthmic junction)
  - ✓ Can occur only if sperm and ovum are transported he simultaneously to the ampullary region. (not all copulation lead to fertilization and pregnancy)
  - ✓ Sperm viability – 24 - 48 hours , egg – 48 -72 hours

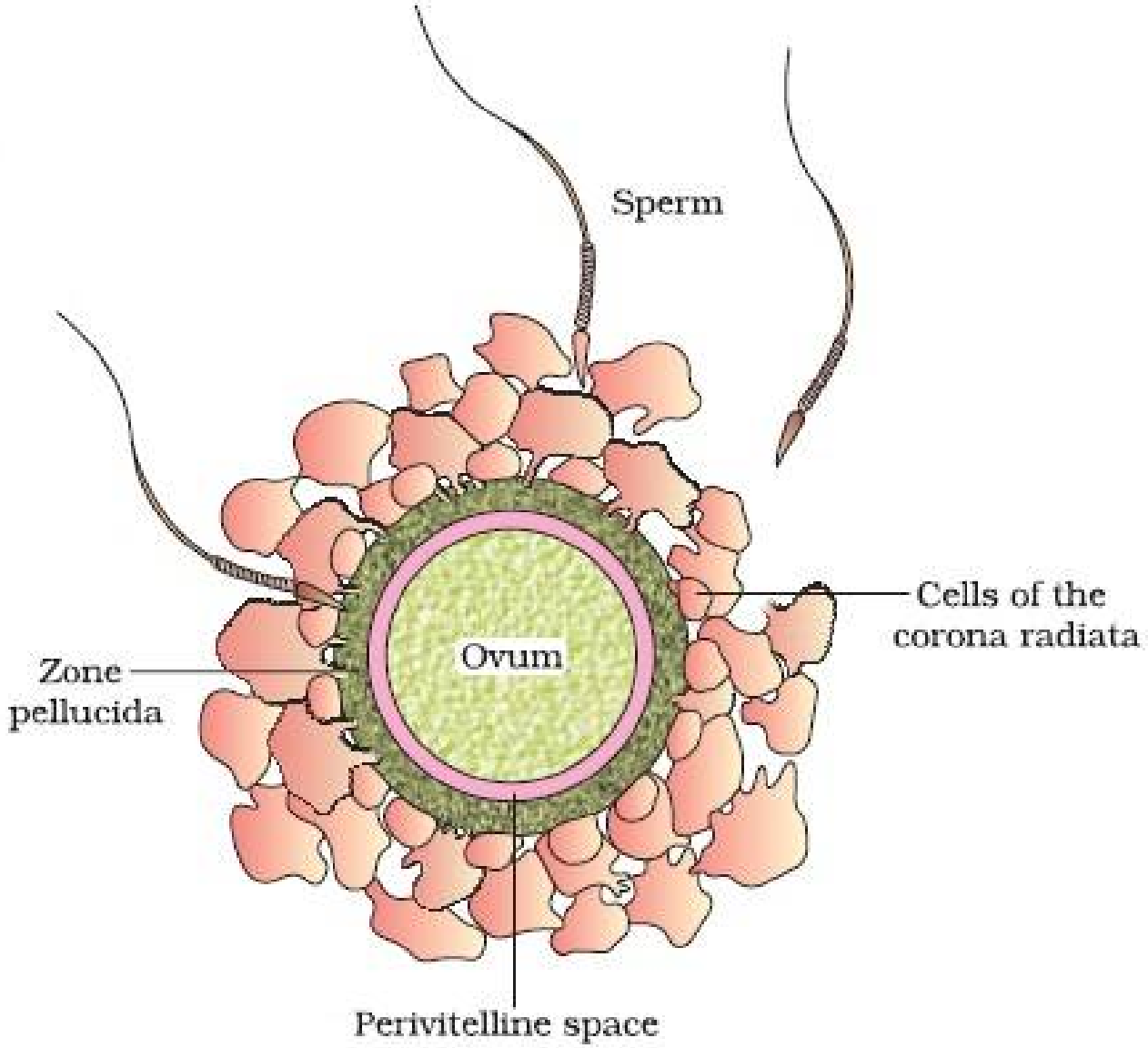


Figure 3.10 Ovum surrounded by few sperms

Steps –

1. Capacitation – physiological maturation of sperms inside female reproductive tract (becomes hyperactive), takes 6-7 hours
   - ✓ Destabilization of PM of sperms, influx of calcium ions into sperms, becomes hypermotile, prostaglandins of semen and vagina helps to propel sperms forwards towards uterine cavity and FT
2. Antifertilin – fertilin reaction (acidic protein on sperm surface and glycoprotein/ ZP3 on egg surface)
   - ✓ Leads to agglutination
   - ✓ Chemo attraction – binding of sperms to egg surface (species-specific method of reproductive isolation)

3. Acrosome reaction – when sperm binds to zp3 receptor on zona pellucida of ovum
   - ✓ Exocytosis of sperm lysins of acrosome (due to calcium ions) – hyaluronidase (dissolves hyaluronic acid), corona penetrating enzyme (digest corona), acrosin/ zona lysin
   - ✓ At end – oolema protrudes out to form fertilization cone/ cone of reception
   - ✓ Fast block to polyspermy – depolarization of oolema due to opening of Na+ channels
4. Cortical reaction –
   - ✓ Sperm touches oolema – calcium ions influx into ooplasm – fusion of cortical granules with oolema – exocytosis of cortical granule substance into perivitelline space

5. Zona reaction – hardening and thickening of ZP
   - Note: cortical and zona reaction leads to formation of fertilization membrane – slow block to polyspermy (due to calcium ions)
6. Entry of sperms into ooplasm – whole sperm enters but later middle piece and tail degenerates
   - ✓ completion of meiosis – II of secondary oocyte
   - ✓ Sperm turn of MPF and turn on APC
   - ✓ Second polar body thrown out into perivitelline space - degenerates
   - ✓ Ovum (haploid, n= 23) becomes active
   - ✓ Mitochondrial inheritance is maternal
   - ✓ Centriole of zygote is paternal

7. Syngamy – plasmogamy, karyogamy (nuclear membrane of both nuclei dissolve), amphimixis (chromosomal membrane dissolve), zygote nucleus/ synkaryon, zygote
   - ✓ Zygote is the first cell of new individual
   - ✓ Significance of fertilization –

1. To block polyspermy
2. To restore diploidy
3. Determination of sex - decided at time of fertilization, male (father) decide the sex

Mechanism of fertilization :

1. **Movement of sperms towards the secondary oocyte.**

↓

2. **AF-F Reaction**

↓

3. **Adherence of sperm to the ZP_3 receptors on zona pellucida, the glycoprotein layer surrounding the oocyte**

↓

4. **Sperm bind to a sperm receptor on the zona and this leads to initiation of acrosomal reaction. Various enzyme are released. Eg. Hyaluronidase, Acrosin (Zona lysin).**

↓

5. **Acrosin faciliate the penetration of sperm through zona pellucida.**

↓

6. **Fusion of sperm and membrane of secondary oocyte. (Syngamy)**

↓

7. **Phagocytosis of sperm by the secondary oocyte.**

↓

8. **Completion of meiosis-II of secondary oocyte during phagocytosis to form ovum and simultaneously it releases 2^{nd} polar body.**

↓

9. **Structural changes in zona pellucida through cortical reaction and discharge of cortical granules in perivitelline space form fertilization membrane.**

↓

10. **In the event of fertilization complete sperm enters inside the ovum. (By phagocytosis)**

↓

11. **It is followed by plasmogamy, karyogamy and amphimixis i.e. completion of fertilization.**

Embryogenesis –

Zygote – cleavage – morula – blastula – gastrula – nurula – organogenesis

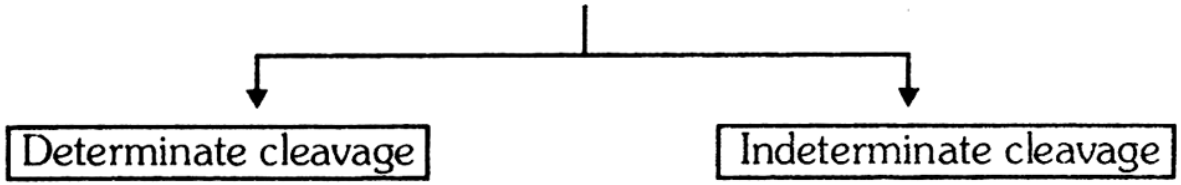
- ✓ Study of first 8 weeks of pregnancy after fertilization (= embryo)
- ✓ Father of animal embryology – Karl Von Baer

- **Cleavage :**
  - ✓ Rapid mitotic division, starts as the zygote moves through the isthmus of oviduct towards uterus
  - ✓ Interphase is only S- phase (G_1/G_2 absent / negligible)
  - ✓ Size of daughter cells (= blastomeres) gradually decreases (nucleo- cytoplasmic index increase)
  - ✓ First cleavage – 30 hours after fertilization (on day 2)
  - ✓ Second cleavage – 40 hours (on day 2), third cleavage – 72 hours (on day 3)
  - ✓ First cleavage – meridional, second cleavage – meridional, at right angle to first cleavage, third cleavage – equatorial
  - ✓ Holoblastic, equal, rotational and indeterminate cleavage in human
  - ✓ Monozygotic twins – if after first cleavage, 2 cells are incidentally separated

	Cleavage	Normal Mitosis
(1)	Newly formed cells are known as blastomeres	Newly formed cells are known as daugther cell
(2)	Interphase is short, only 'S' phase are present	Interphase are long G, S, G_2 phase are present
(3)	Karyoplasmic index increses	Karyoplasmic index remain constant.

CLASSIFICATION OF CLEAVAGE

On the basis of fate of blastomere



The fate of blastomere is fixed, determined i.e. blastomere forms a particular portion of embryo
eg. Nematoda, annelida, mollusca

The fate of blastomere is not definite. These are totipotent in early stage of embryo
eg. Human

Complete or holoblastic
- **When cleavage furrow passes through the egg completely**
- **Whole egg divides**

Meroblastic
- **Cleavage does not occur in the part of egg. where Yolk in present**
- **Cleavage occurs only in cytoplasmic part**
- **Found in Megalecithal eggs.**

Equal holoblastic
- **Blastomere are of same size**

eg. Homolecithal/isolecithal egg. Mammals (eutherian, metatherian)

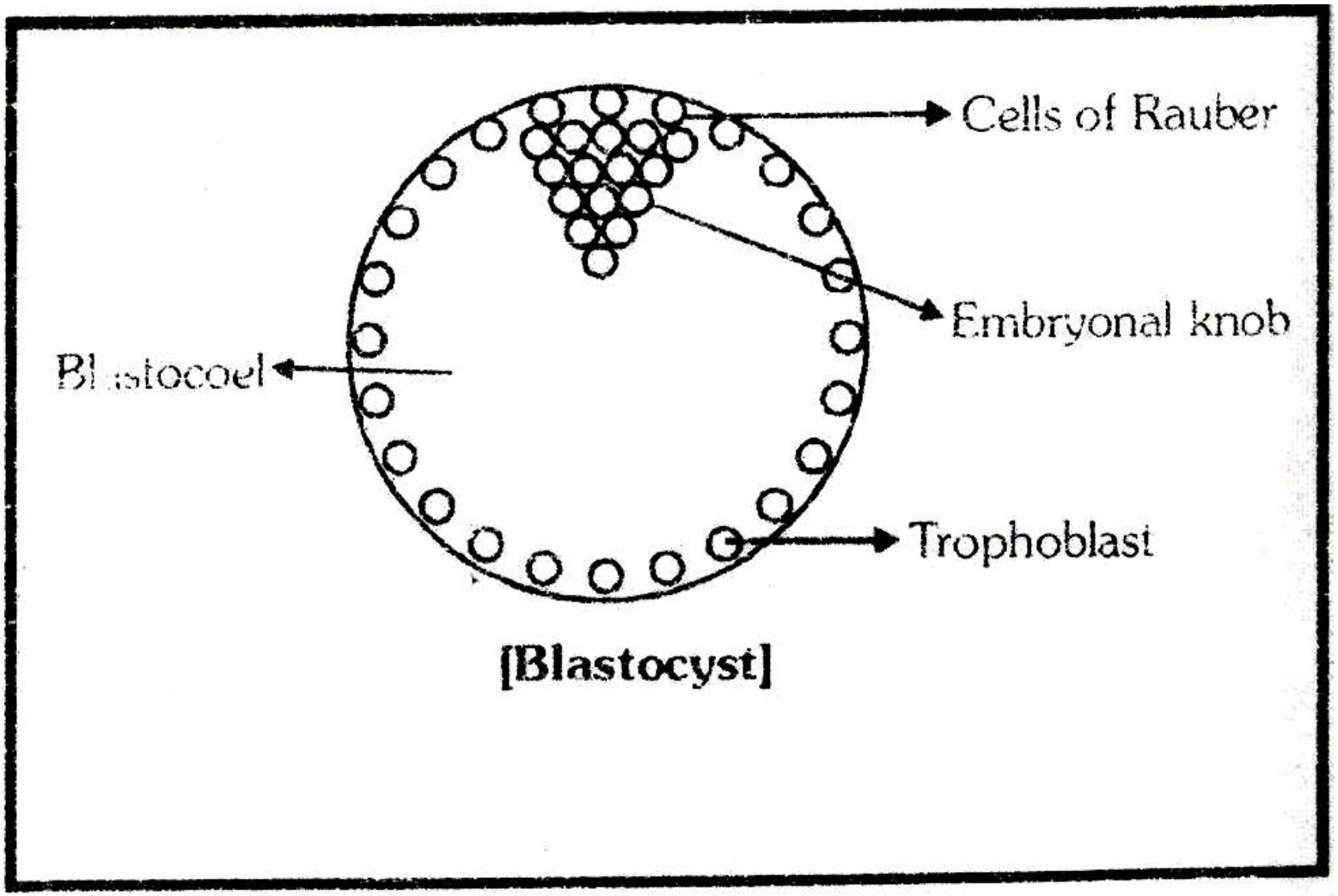
Unequal holoblastic
- **Blastomere unequal size**

eg. Mesolecithal, Frog

Discoidal meroblastic cleavage
eg. Birds, Reptile, Protoherian mammals

Superficial Meroblastic Cleavage
eg. Centrolecithal egg of insects

- Morula – after third cleavage on third day
  - ✓ Solid ball of 8-16 celled stage, surrounded by ZP
  - ✓ Embryo is solid, mulberry ball like (compaction)
  - ✓ Present in fallopian tube
- Blastocyst – characterized by cavitation inside embryo
- Blastocyst In marsupials and eutherian mammals, blastula in other animals
  - ✓ Starts from day 4
  - ✓ By day 5-When enters into uterine cavity, ZP degenerates and embryo hatches out (64-128 cell stage)
  - ✓ Ectopic pregnancy
  - ✓ ZP prevents premature implantation of embryo
  - ✓ Blastomeres arranged into two layers:



[Blastocyst]

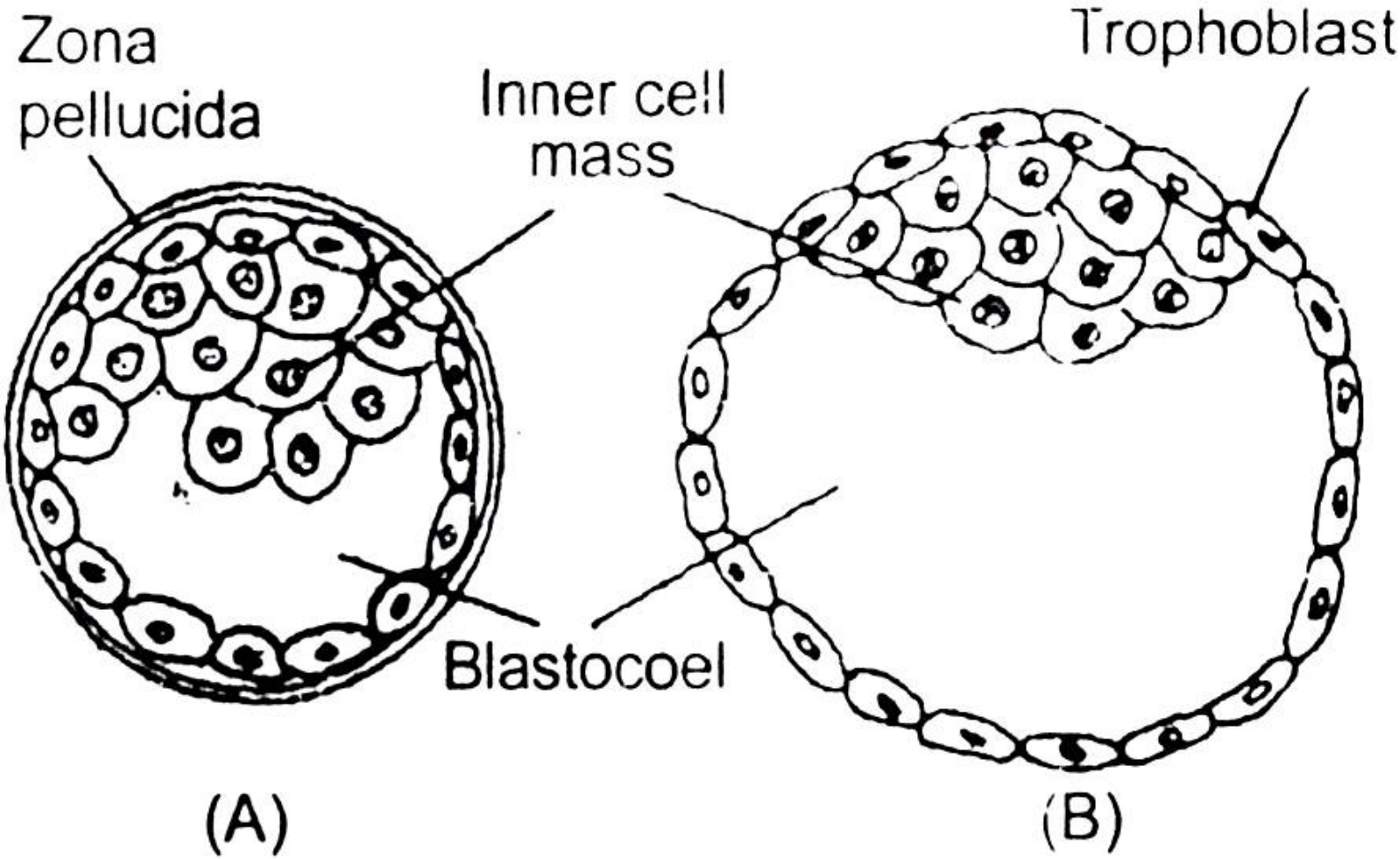


Fig. : Development of blastocyst

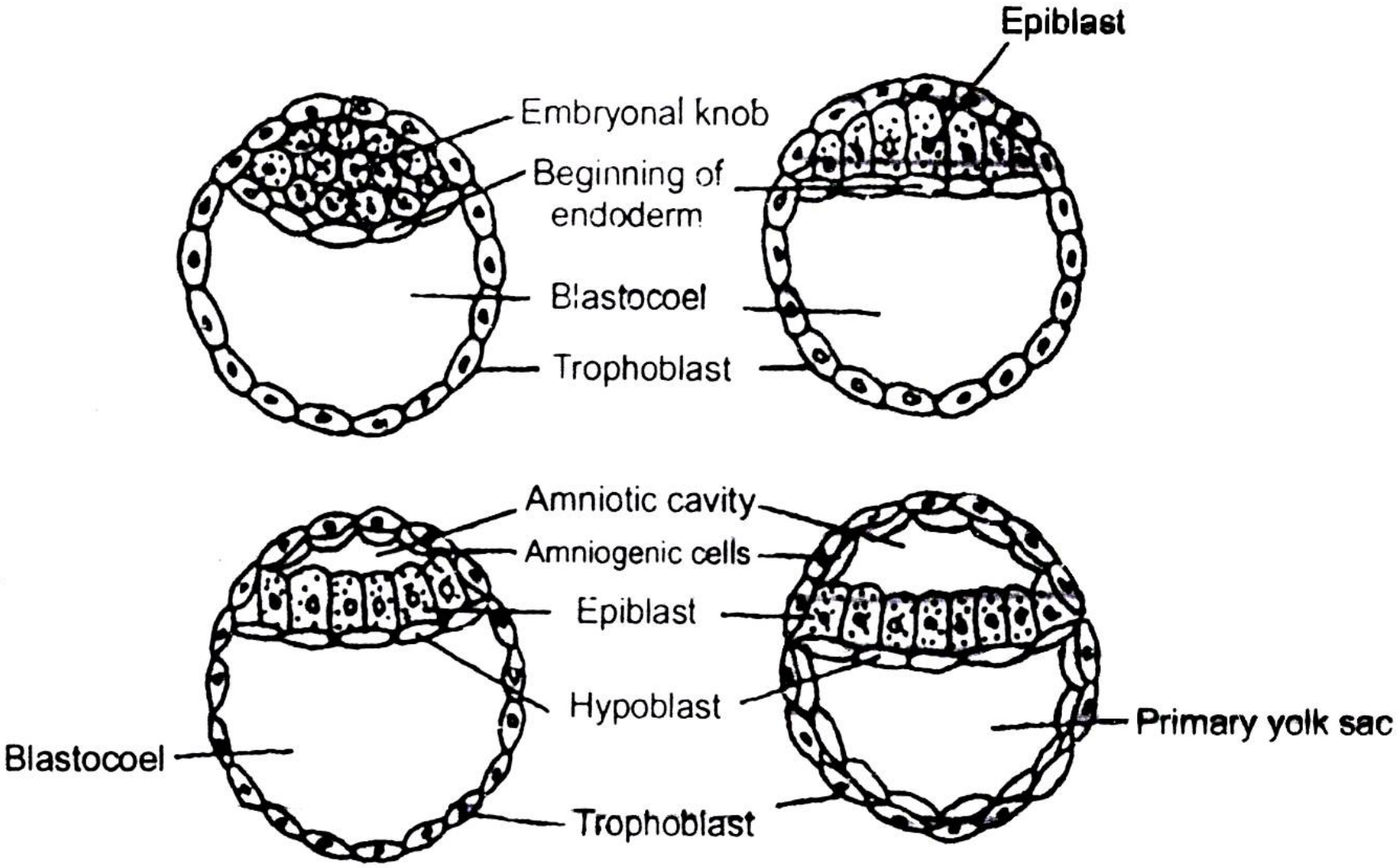


Fig. : Formation of endoderm and amniotic cavity

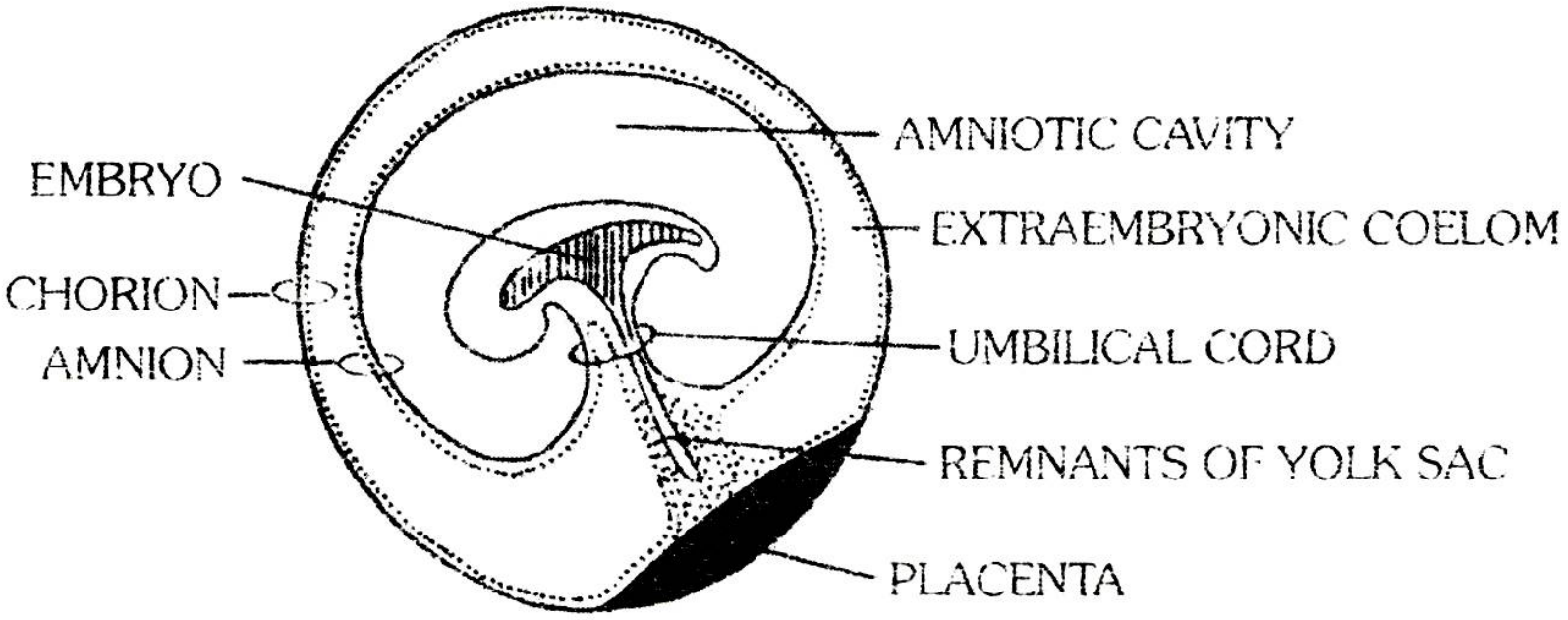
1. Outer trophoblast – produce chorion fetal membrane that contributes in making of placenta, protective
2. Inner layer ICM / inner cell mass or embryonal disc proper – forms amnion, allantois and yolk sac fetal membrane and complete embryo body
   - ✓ Trophoblast layer gets attached to endometrium. After attachment, uterine cells divide rapidly and covers blastocyst. Thus it becomes embedded in endometrium, called implantation, leading to pregnancy

- Implantation / nidation of blastocyst (embryo) occurs on day 6th or 7th post- fertilization
  - ✓ On day 8th, trophoblast- outer syncytiotrophoblast (many free nuclei) and inner cytotrophoblast
  - ✓ Syncytiotrophoblast forms finger like projections- chorionic villi (to form placenta)
  - ✓ Trophoblast secrete hCG hormone from day 8 onwards till 12 weeks of pregnancy (maintains CL for first 3 months, rescues dying CL)/ urine pregnancy test/ gravidex test
  - ✓ On day 8th, ICM- upper epiblast and lower hypoblast (primitive endoderm)

- Extra- embryonic membranes-

1. Chorion – cytotrophoblast + extra – embryonic mesoderm, protection to embryo, placenta formation (chorionic villi)
2. Amnion – extra- embryonic mesoderm + ectoderm (epiblast)
   - ✓ Forms amniotic cavity filled with amniotic fluid, acts as shock absorber, prevents embryo from desication(land adaptation)
3. Yolk sac – extra- embryonic mesoderm + endoderm (hypoblast)
   - ✓ In Birds and reptiles, filled with yolk (nutritive)
   - ✓ In human, regress after 8 weeks – Haemopoietic and formation of male and female germ cells

4. Allantois – extra- embryonic mesoderm + endoderm (Hypoblast)
   - ✓ In Birds and reptiles – called urinary bladder of embryo , stores uric acid (nitrogenous waste)
   - ✓ In human – formation of umbilical blood vessels and Wharton’s jelly



Formation of extraembryonic membranes in human

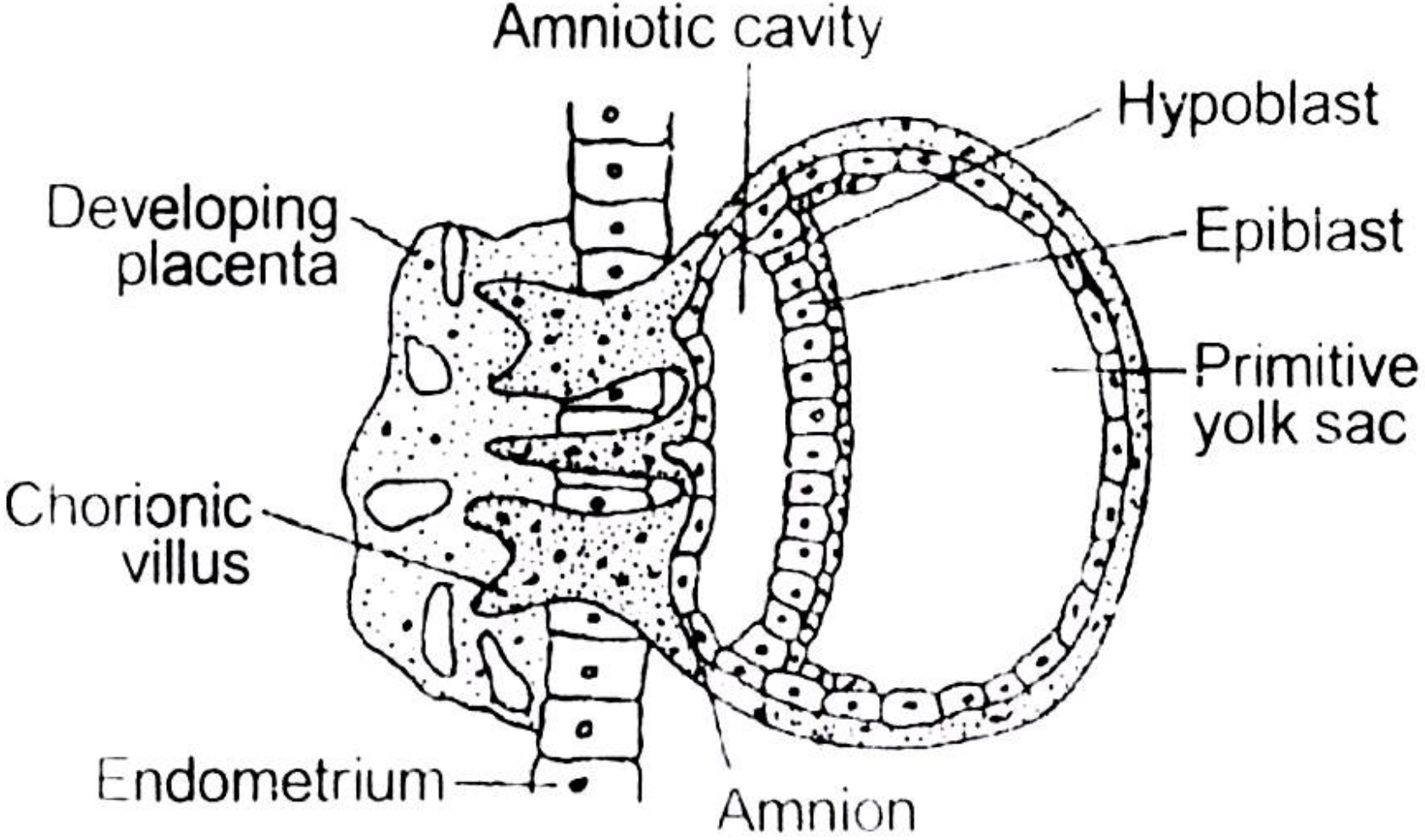


Fig. : Implanted blastocyst

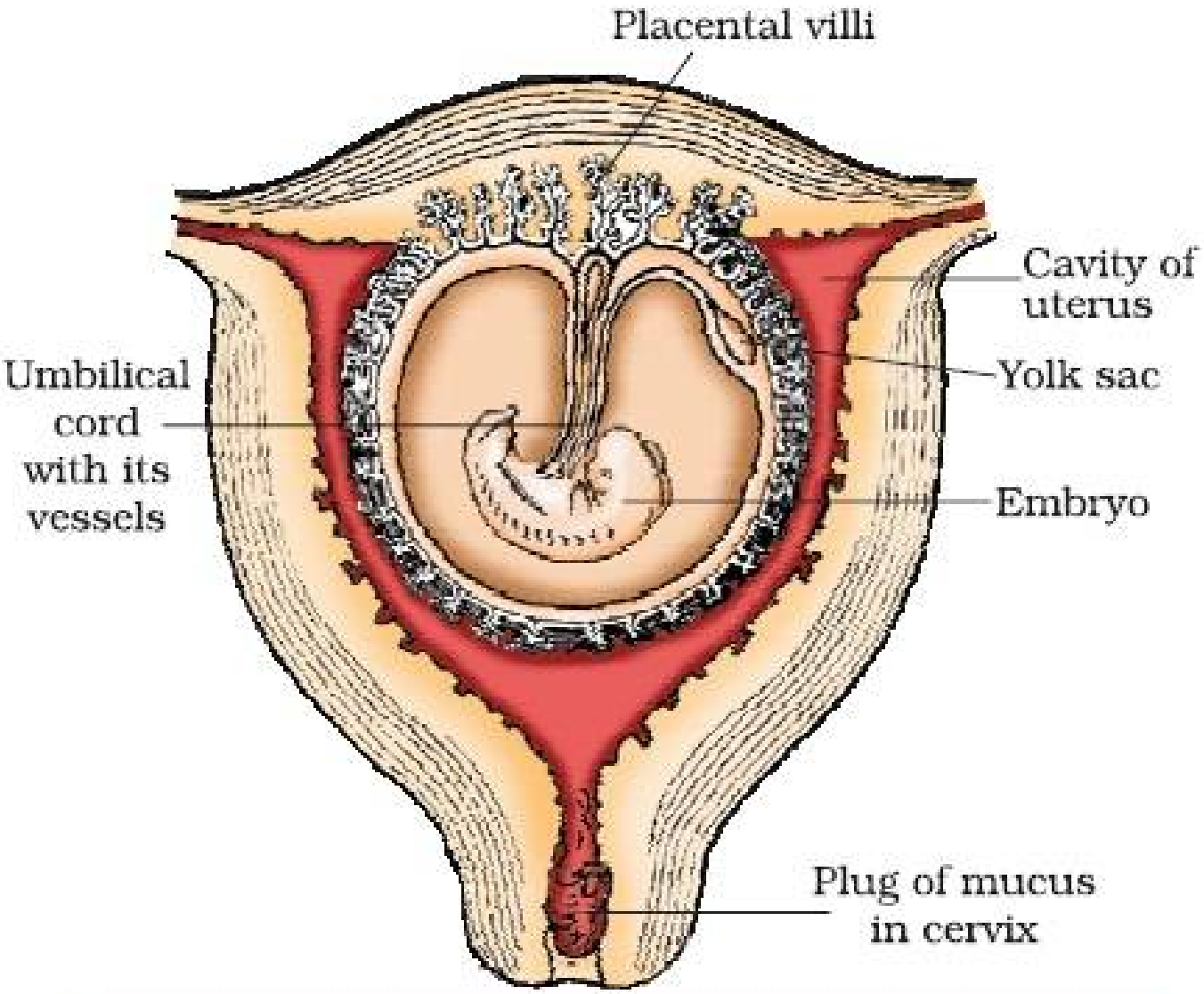
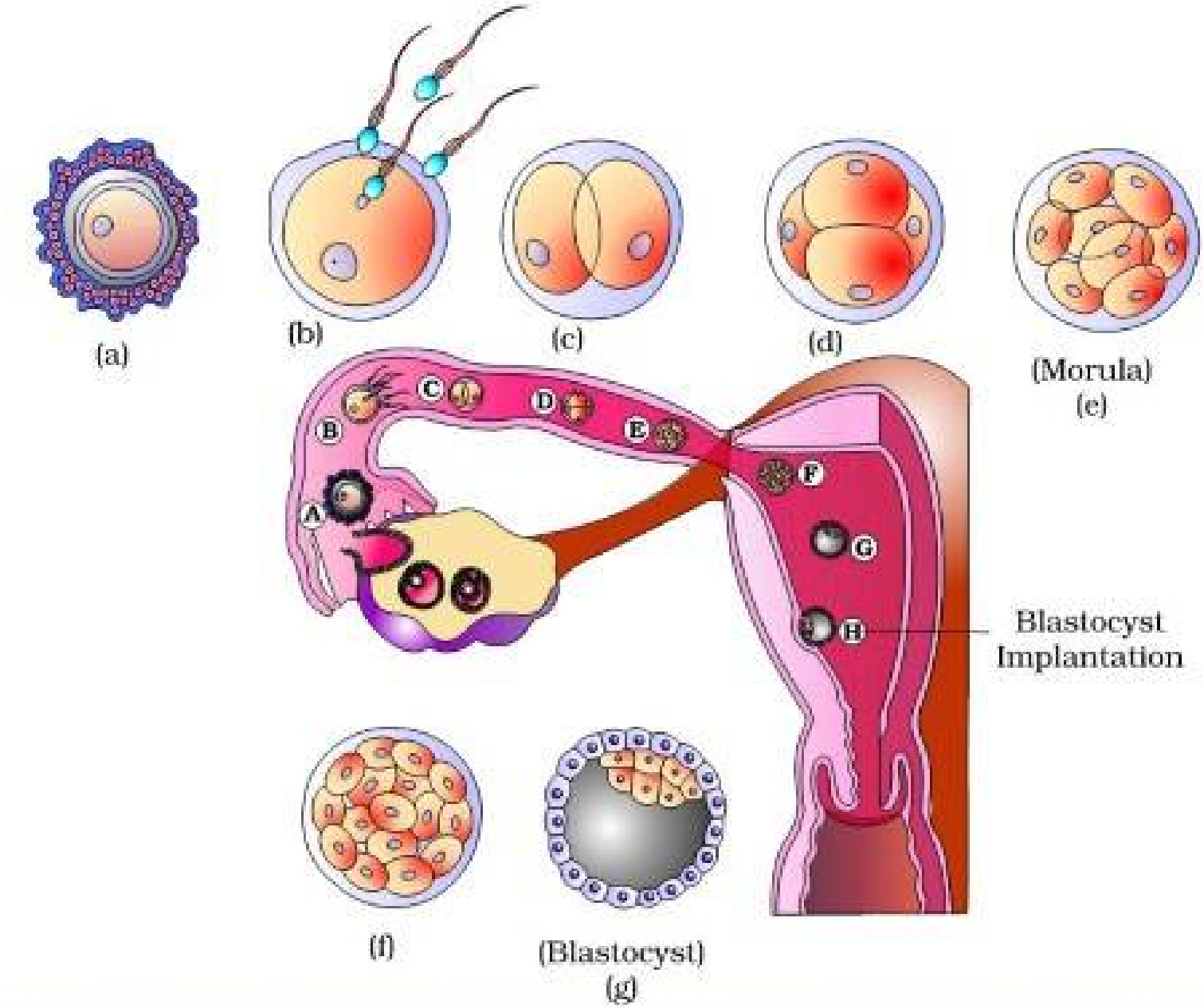
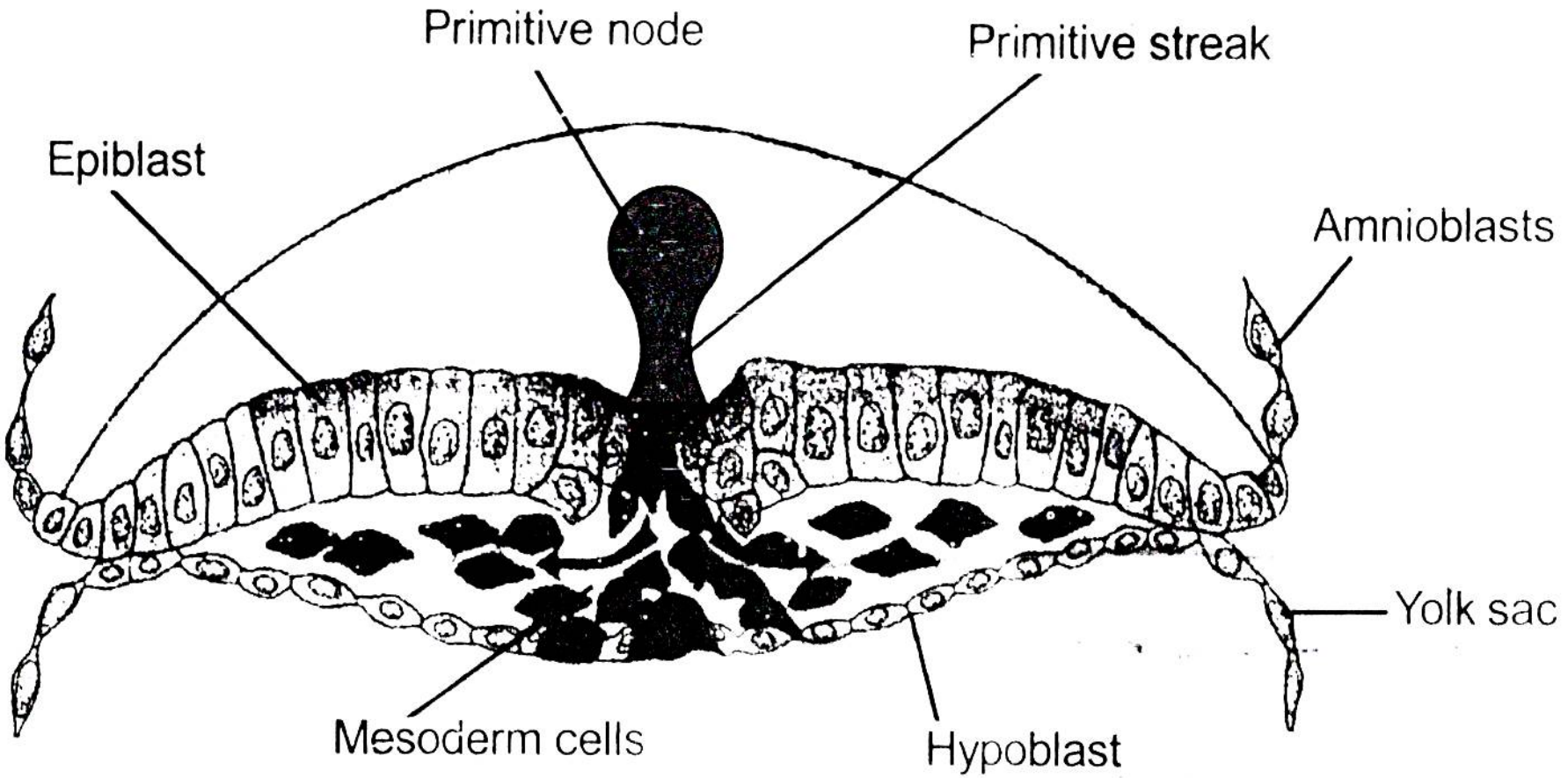


Figure 3.12 The human foetus within the uterus



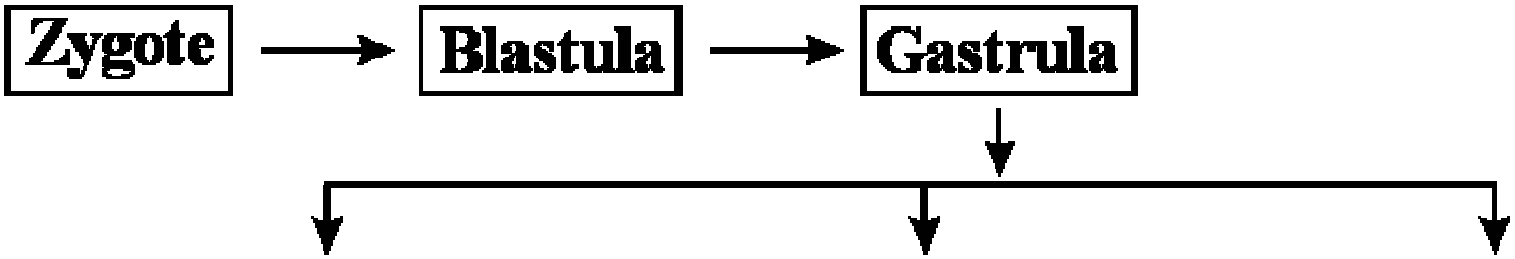
1 Transport of ovum, fertilisation and passage of growing embryo through fallopian tube

- Gastrulation – formation of 3 primary germ layers from bilaminar disc.
  - ✓ Day 15 – primitive streak appearance on dorsal surface of epiblast and this marks the beginning of gastrulation
  - ✓ Primitive streak runs from tail to head part and decides embryonal axis and bilateral symmetry
  - ✓ Dynamic process – emboly (d lamination) i.e. sheat of cells moves
  - ✓ Epiblast has prospective endodermal and mesodermal cells (source of all three germ layer)
  - ✓ Hypoblast contributes in formation of endoderm
  - ✓ First germ layer formed – endoderm (by delamination of prospective endodermal cells from epiblast, between hypoblast layer)
  - ✓ First organ formed – Heart (21 days after fertilization/ after one month of pregnancy)


Primitive node
Primitive streak
Epiblast
Amnioblasts
Yolk sac
Mesoderm cells
Hypoblast

- ✓ First organ system formed – nervous system
- ✓ ICM contains stem cells which has potency to give rise to all tissues and organs
- ✓ Nervous system develops from ectoderm
- ✓ First sign of growing fetus is noticed by listening heart sound through stethoscope
- ✓ By end of second month – limbs and digits developed
- ✓ By end of 12 weeks / first trimester – most of the major organ system formed (limbs and external genital organs well developed)
- ✓ During 5^{th} month – first movement of fetus and appearance of hair on head
- ✓ By end of 24 weeks / end of second trimester- body covered with fine hair, eyelids separate, eye lashes formed
- ✓ By end of nine months – fetus fully formed, ready for delivery

Fate of Germ Layers :



Ectoderm	Mesoderm	Endoderm
Epidermis	Dermis	Gut
Cutaneous glands	Muscular tissue	Visceral organs
Nervous system	Connective tissue	Glands of stomach and
(Brain and spinal cord)	Endoskeleton	intestine
Eye (Retina, lens and cornea)	Vascular system	Tongue
Nasal epithelium	Blood (heart and blood vessels)	Lungs, trachea and bronchi
Internal ear and external ear	Kidneys	Urinary bladder
Lateral line sense organ	Gonads	Gills
Stomodaeum	Urinary and genital ducts	Liver and pancreas
Proctodaeum	Coelom and coelomic epithelium	Thyroid gland
Pituitary	Choroid and sclerotic coats of	Parathyroids
Pineal gland	eye	Thymus
Adrenal medulla	Adrenal cortex	Eustachian tube
	Spleen	

- **Placenta:**
  - ✓ Structural and functional unit between developing embryo (fetus) and maternal body
  - ✓ Chorionic villi and uterine tissue become interdigitated
  - ✓ In primates(including human) – haemo- chorial placenta (3 foetal barriers present, all 3 maternal barriers lost i.e. maternal blood bathes fetal chorion)
  - ✓ In mammals – chorio- allantoic placenta but in human – chorionic placenta
  - ✓ Mammals (including human) – deciduate placenta (both fetal and maternal parts delivered)

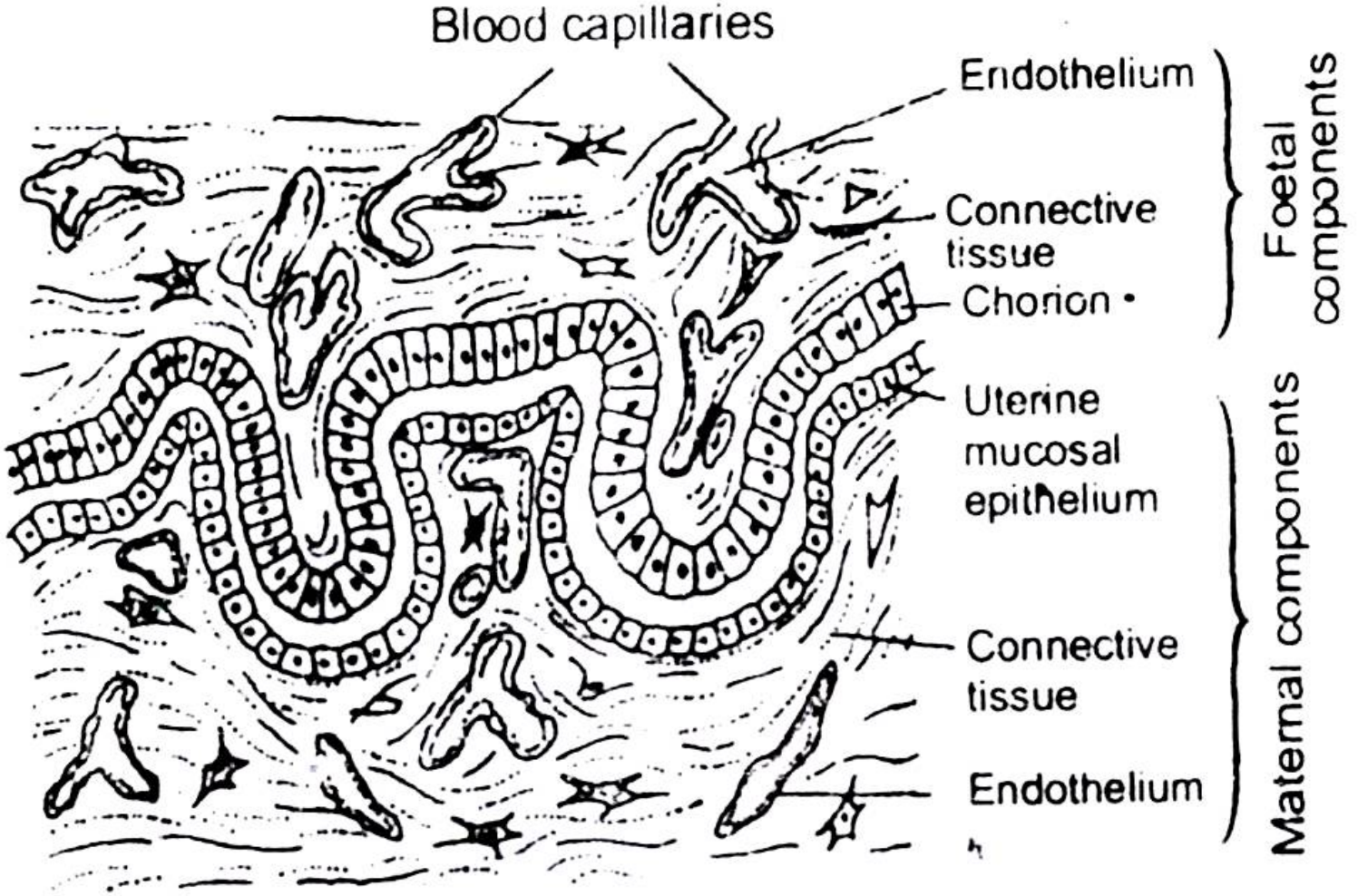


Fig. : Structure of typical placenta

- ✓ In humans – meta-discoidal placenta (chorionic villi were diffuse initially but later forms cluster / disc)
- ✓ Maternal contribution – decidua basalis (endometrium, uterine tissue)
- ✓ Fetal contribution – chorion
- ✓ Temporary organ
- ✓ Fully developed by 10-12 weeks of pregnancy
- ✓ Acts as barrier between maternal and fetal blood(their blood does not get mixed)

❖ **Functions :**

1. provide nutrients to fetus
2. gaseous exchange (O2- CO2) – called fetal lung
3. waste elimination from fetus into maternal blood
4. provides immunity to fetus (via IgG antibodies from mother)
5. Temporary endocrine gland
   - ✓ Placenta is connected to embryo through umbilical cord which helps in transport of substances to and from embryo (2 umbilical artery – deoxygenated blood, 1 umbilical vein – oxygenated blood)
   - ✓ Umbilical vessels have 100 % fetal blood

- **Hormones produced by placenta –**
  1. Progestogens- maintains pregnancy and increase number of milk alveoli in mammary gland
  2. Estrogens – proliferates endometrium and breast development during pregnancy
  3. Human chorionic gonadotropin (hCG)- max at 12 weeks, maintains CL in first trimester
  4. Human chorionic thyrotropin (hCT)- stimulates maternal thyroid gland – physical and mental development of fetus
  5. Human chorionic somatomamotropin (hCS) / human placental lactogen (hPL) – helps in milk secretion

6. Human chorionic corticotropin (hCACTH)- placental steroidogenesis- increase estrogen at delivery, determine time of child birth
7. Relaxin – peaks at 14 weeks and at delivery(later phase of pregnancy)
   - ✓ At delivery – produced by ovary (CL) and placenta, relaxes pubic symphysis and pelvic ligaments for easy child birth
   - ✓ Note :-hCG, hPL, hCACTH, hCT relaxin are produced in women only during pregnancy
   - ✓ During pregnancy levels of estrogens, progestogens, cortisol, prolactin, thyroxin etc are increased several folds in maternal blood, essential for supporting fetal growth, metabolic changes in mother and maintenance of pregnancy

- **Pathogens which cross placenta –**
  - ✓ Toxoplasma, rubella virus, CMV, HSV, varicella virus (chickenpox), treponema pallidum (syphilis), HBV, HIV etc

- **Gestation period:**
  - ✓ Time between conception to birth
  - ✓ 266 days / 38 week (from fertilization)
  - ✓ 280 days / 40 weeks (from LMP)
  - ✓ Dogs – 60-65 days, cat – 52-65 days, elephants 22 months (607 – 641 days, longest gestation period)
  - ✓ Teratogens/ monster forming agents – substances which produce malformed fetus, most sensitive during first 12 weeks of pregnancy.eg. Thalidomide drug (given for morning sickness, cause phocomelia – malformed limbs, like seal)

Gestation period -

- Duration between fertilization and Parturition.
  1. Rabbit = 28 – 32 days
  2. Man = 270 – 290 days
  3. Dog = 60 – 65 days
  4. Cat = 62 – 72 days
  5. Elephant = 607 – 641 days

Gynaecomastia – Development of breast in the male.

Hystereotomy – Surgical removal of uterus.

Oopherectomy – Removal of ovaries.

- **Parturition –**
  - ✓ Process of delivary of fetus/ child birth / expulsion of baby out of uterus through birth canal
  - ✓ Caused by vigrous contraction of uterus (myometrium) at end of pregnancy
  - ✓ Induced by complex neuroendocrine mechanism
  - ✓ First stimulus originate from fully developed fetus and placenta, which induces mild uterine contraction called foetal ejection reflex (FER)
  - ✓ Oxytocin acts on uterine muscles and cause stronger uterine contraction, which inturn stimulates further oxytocin secretion, resulting in stronger and stronger contraction
  - ✓ Soon after infant is delivered, the placenta is expelled out of uterus (stage of after birth)

- **Lactation-**
  - ✓ Helps mother in feeding the new born
  - ✓ Milk secretion/ production – prolactin, hPL
  - ✓ Milk ejection- oxytocin (contraction of myoepithelial cells)
  - ✓ Colostrum – milk produced during initial few days of lactation, contains IgA antibodies (provides passive immunity to new born, essential to develop resistance for new born)
  - ✓ Breast feeding during initial period of infant growth is recommended by doctors for bringing up a healthy baby